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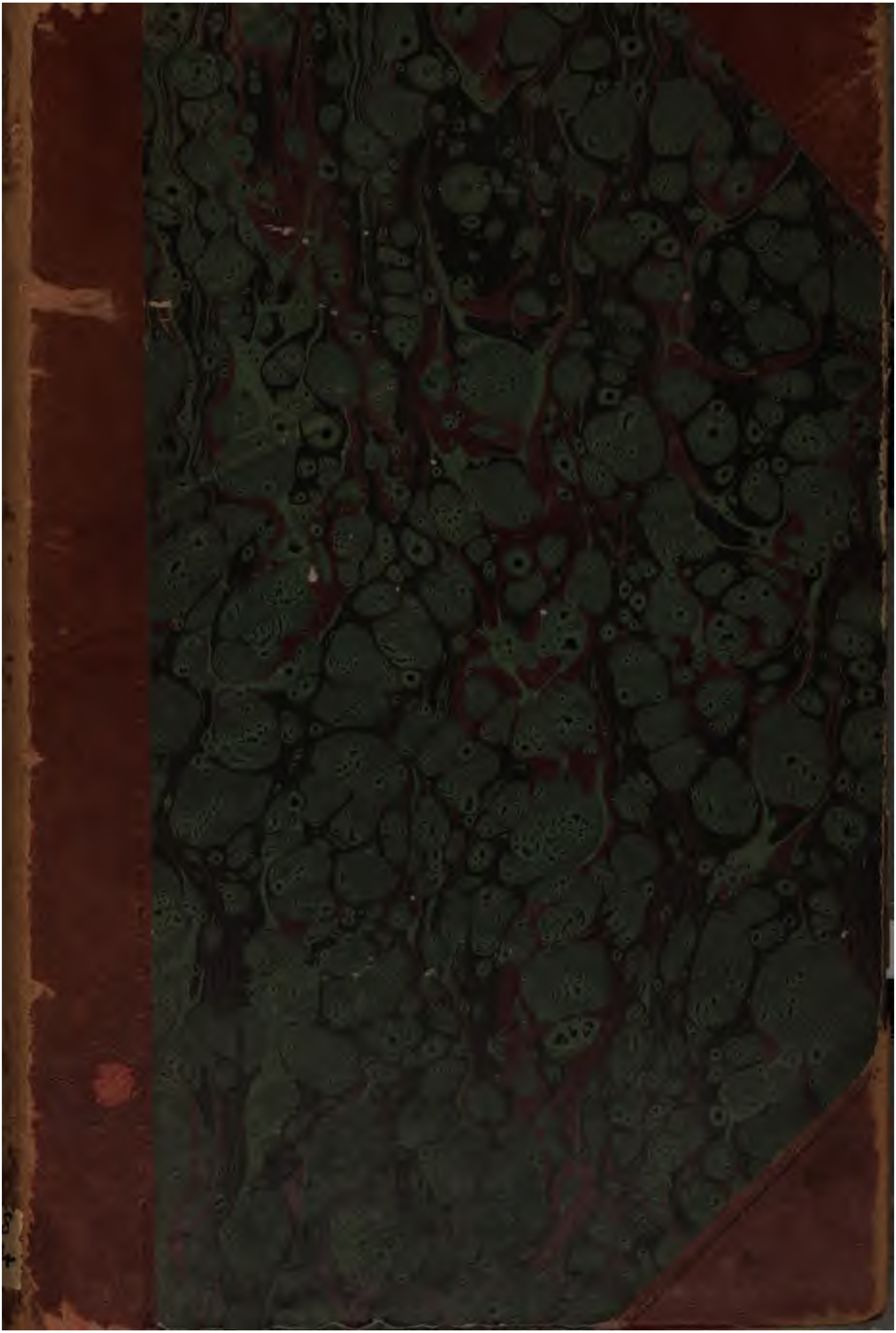

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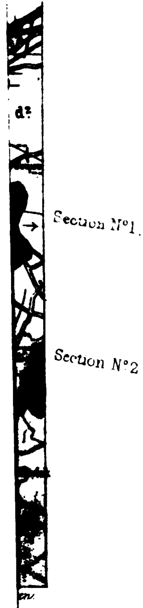

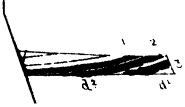

32.—SCOTLAND.

MEMOIRS
OF THE
GEOLOGICAL SURVEY
OF
GREAT BRITAIN
AND OF THE
MUSEUM OF PRACTICAL GEOLOGY.

THE GEOLOGY OF
THE NEIGHBOURHOOD OF EDINBURGH.
(MAP 32.)

BY

H. H. HOWELL, F.G.S.,

AND

ARCHIBALD GEIKIE, F.R.S.E. & G.S.

APPENDIX AND LISTS OF FOSSILS BY J. W. SALTER, F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

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NOTICE.

THE first published sheet of the Geological Survey in Scotland, that which contains the metropolis of the kingdom, is illustrated in the present Memoir through the joint labours of MM. Howell and Geikie.

The origin and prosecution of the Surveys of Edinburghshire and Haddingtonshire, as ably devised and carried out under the local direction of Professor Ramsay, is clearly explained in the Preface to this Memoir.

It would be unbecoming on my part to select for special approbation any one portion of the Survey of the British Isles; but I may truly say, that of the many maps we have published (and the rapid sale of them attests their value), there is, perhaps, no one which conveys a greater amount of useful knowledge than the sheet representing the country in and around Edinburgh, the authors of which are entitled to great credit for the manner in which they have completed their task.

RODERICK I. MURCHISON,
Director-General.

IN the year 1855 the Ordnance Survey had made so much progress in surveying part of the Eastern Counties of Scotland, that many of the Maps on a scale of six inches to a mile were engraved. On consultation with the late Director-General, Sir Henry De la Beche, the time seemed to have arrived for extending the Geological Survey of Great Britain into Scotland. We also considered it desirable to commence the work in such a way that it would bring the survey as quickly as possible into the great Coal-fields of Scotland, but the Ordnance Survey of the Western Counties being then scarcely commenced, we deemed it best to begin the Survey amongst the Old Red Sandstone and Carboniferous rocks of Berwickshire and Haddingtonshire, unusually perfect sections of these strata being exposed on the sea cliffs between North Berwick and the base of the Old Red Sandstone west of St. Abb's Head. In doing so it was felt that a key might be obtained to the right understanding of these strata in inland areas, where the rocks are often much concealed by deep superficial accumulations of drift. Accordingly, I personally commenced the mapping of that district, extending my work southward to the Lammermuir Hills, and westward beyond Belhaven, and by degrees, as the Survey progressed, it was extended by Mr. Howell and Mr. Geikie into the rest of Haddingtonshire, Edinburghshire, and Fifeshire. During the progress of the work I superintended and examined the whole, and occasionally assisted when doubtful questions arose, and I believe that the mapping of the outline of the different formations of the beds of coal, the limestones, igneous rocks, faults, &c., is as accurate as the data and the present state of geological science will permit.

In the Edinburgh sheet the whole of the district east of the fault that bounds the Pentland Hills was surveyed by Mr. Howell, taking it in connexion with his work in Haddingtonshire; and the Pentland Hills and all to the west of them were mapped by Mr. Geikie. In the following Memoir each has described the area mapped by himself.

In surveying the united area of East and Mid Lothian it so happened that the sheet of map comprising most part of Edinburghshire was completed and published first. Since then, Sheet No. 33 (Haddingtonshire) has also been published, and the Memoir descriptive of the district is in progress. Fife and Kinross and part of Berwickshire are also far advanced.

It will be observed that this Memoir refers directly to the one-inch maps of the Geological Survey, but six-inch maps of those parts of the Carboniferous strata that contain beds of workable coal, and sections on the same scale, to be accompanied by printed descriptions, are very far advanced.

ANDREW C. RAMSAY,
Local Director of the Geological Survey
of Great Britain.

Geological Survey Office,
June 1861.

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GEOLOGY OF THE NEIGHBOURHOOD OF EDINBURGH.

CHAPTER I.

PHYSICAL FEATURES OF THE DISTRICT, AND GENERAL DESCRIPTION OF THE ROCKS.

THE area comprised in this Sheet includes the greater part of the counties of Edinburgh and Linlithgow, with portions of Fife, Haddington, and Peebles. Its physical features present that union of level cultivated plains, with undulating and hilly ground, varied by the frequent occurrence of abrupt solitary crags, which forms the characteristic scenery of central Scotland. It is divided into two well-marked portions by the chain of the Pentland Hills, which traverses its centre from south-west to north-east, and rises to a height of 1,898 feet above the sea. The eastern area consists of a broad plain, which, from the foot of the hills, stretches eastward into Haddingtonshire, and southward until it abuts against the slopes of the Moorfoots. With the exception of the minor undulations incident to a drift-covered district, the continuity of this plain is unbroken, save by the long ridge of the Roman Camp Hill, which, beginning near the sea at Prestonpans, and running south-west parallel to the Pentlands, divides the plain into two, the western portion being known as the Mid Lothian coal-field, while that to the east includes the coal basin of East Lothian. The margin of the Firth of Forth truncates both coal-fields, the coal seams passing under the sea, and re-appearing on the opposite shores of Fife.

The great central ridge of the district may be regarded as commencing at the Braid Hills, whence it stretches south-west through the Pentland Hills, till it merges into the uplands of Peebles and Lanark. The anticlinal axis which coincides with this central ridge runs through the town of Edinburgh, Arthur's Seat and the Calton Hill lying on its eastern side. The district to the west of this chain of hills comprises nearly two-thirds of the present sheet, and presents a physical contour considerably different from that described on the east side. With the exception of the broad plain which extends for seven miles to the west of Edinburgh, this western division contains few level spaces of any extent. Throughout the greater part the surface undulates in ridges, of which the general direction may be taken as east and west, but their continuity seldom remains persistent, more frequently they coalesce or branch out into a new series, the determining cause being, in many cases, some prominent crag or hill of trap. While, therefore, most of the valleys by which this area is traversed extend in an easterly and westerly direction, the general course of the streams is from south-west to north-east, *i.e.* at an acute angle across these valleys. This feature is well exhibited by the Water of Leith, which, for upwards of three miles, between Malleny and Colinton, flows in a nearly straight channel along the declivity that descends from the foot of the Pentland Hills. It is only at Colinton, where the channel of the stream is formed on one side by a cliff 80 to 100 feet high, of hard sandstone, that it turns sharply to the north-west, and at nearly right angles to the prevailing ridges, breaks into the plain below Slateford.

The Firth of Forth separates the area described above from the county of Fife, of which a small portion is embraced in this Sheet. The physical features of that portion are those of a trappean district, thickly covered with drift and alluvial sand. At Inverkeithing and North Queensferry the ground consists of abrupt greenstone hills, separated by flat plains, only slightly elevated above the sea level. These plains, consisting chiefly of alluvial sand, indicate a former level of the estuary, when the hills around were detached islands, skirting an older coast line. A depression of 50 feet would have the effect of indenting the Fife coast with numerous bays, and fringing it with large islands. Especially would this be the case at Inverkeithing and Burnt Island.

The islands of the Forth consist chiefly of greenstone, and present the usual features of such greenstone hills as are bare and uncultivated. They are lumpy irregular masses of dark grey rock, covered, however, with a rich green herbage that descends to the sea margin, and shows in many places rounded knolls and crags protruding from the rock below. Inchkeith comprises a greater variety of rock, and shows, in consequence, a greater diversity of scenery; its short narrow valleys of soft sandstones, shales, and limestones afford a soil that yields a richer vegetation than the other islands can boast, while the parallel ridges of greenstone exhibit the usual knobs of dark rock appearing from beneath a scanty covering of turf.

Before describing the geology of this Sheet in detail, it will be well to give a brief outline of the general distribution of the rocks, the more especially as such an outline will illustrate how closely connected are the geology and the physical geography of a country. The Pentland Hills, forming the backbone of the region, consist fundamentally of highly inclined Upper Silurian shales and grits, covered unconformably by coarse conglomerates, grits, and sandstones, and great sheets of felstone and ash belonging to the Upper Old Red Sandstone group. These rocks, with very varying outlines, form an anticlinal axis over which the Carboniferous rocks are folded, though, owing to large parallel faults, the regularity of this anticline has been materially disturbed. The country on the east side of the hills, already described as a broad plain, consists entirely of carboniferous strata, extending southward until they abut against the Lower Silurians of the Moorfoot and Peeblesshire hills. They form a synclinal trough, the west side of which flanks the Pentland Hills, while the eastern swells up into the Roman Camp Hill. That hill is an anticlinal axis of Carboniferous Limestone, which, rising from the Mid Lothian basin, folds over this prominent ridge and sinks eastward below the coal basin of East Lothian, until it rises again on the western side of the Garlton Hills. The centre of the Mid Lothian basin consists of coal-bearing strata, the probable equivalents of the lower part of the English Coal-measures. Between the centre and the outer edges is another set of coal-bearing strata, surmounted and underlaid by marine limestones, the whole forming the equivalent, partly terrestrial, partly marine, of the Carboniferous Limestone of England. Along the western side of this basin the strata recline at a very high angle, sometimes even vertical, and the lower series of coals there have hence been termed the "Edge coals," in contradistinction to the upper series or "Flat coals," which lie more or less horizontally in the middle of the trough. The effect of this difference in the angle of inclination is well shown on the map. Along the west side it will be seen that the limestone seams are narrow and lie close together, while along the southern and eastern side, where the angle of dip is low, they broaden out into wide bands. The district between the north end of the Braid Hills and the sea consists of Lower Carboniferous sandstones and shales, which pass down into the Old Red Sandstone of the Pentlands. With these rocks are associated numerous masses of interbedded and intrusive trap, as Arthur's Seat, Calton Hill, and Castle Rock.

The country to the west of the Pentland Hills also consists entirely of Carboniferous rocks. If these hills formed a simple anticline we should find the same strata along their western as along their eastern flank, but the long parallel faults already alluded to have thrown out a considerable thickness of strata on the latter side which are found on the former. This circumstance, along with the undulating nature of the strata, accounts for the great development of Lower Carboniferous beds to the west, and for the much greater distance between the Old Red Sandstone and the Carboniferous Limestone on that side than on the eastern. West of the Pentlands the Lower Carboniferous strata extend in an endless series of anticlines and synclines, varied everywhere by detached masses of greenstone or basalt. Their general dip, however, is westerly, and, in spite of the frequent repetitions, we get a slowly ascending section through the sandstones and shales of this lower series, until we come to the range of hills between Linlithgow and Bathgate, where the Carboniferous Limestone supervenes among sheets of interbedded greenstone, basalt, and ash. The coal-field of Borrowstowness, occupying the upper left-hand corner of the Sheet, is also interstratified with greenstone, and forms the equivalent of the Edge coals of Mid Lothian. The more prominent hills over the whole of this area consist almost uniformly of trap, and the narrow valleys which divide them frequently owe their origin to the denudation of intercalated shales and sandstones, or to lines of fissure along which the denuding agent has acted.

In the following Memoir the rocks are described in ascending series. The same order has been followed with regard to the interbedded traps, which are described in their proper chronological place in the formations among which they occur, in order that the geological sequence of the district may be strictly pursued, and a separate chapter is devoted to the intrusive traps. The same remark applies to the faults; these are referred to where necessary in the description of the formations, but a notice of the more important of them is also added in a separate section.

CHAPTER II.

LOWER AND UPPER SILURIAN, AND LOWER OLD RED SANDSTONE.

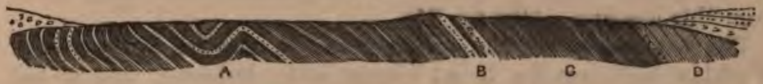
Lower Silurian.—The only portions of Lower Silurian in this Sheet are of small extent, and form part of the northern edge of the great Silurian region of South Scotland. The larger portion occurs about three miles south-east of Penicuick, in the form of an obtuse promontory running into and overlapped by the Mid Lothian coal-field. It consists of hard grits and shales, striking north-east and south-west at high angles. The other piece of Lower Silurian in this Sheet occupies a small part of the south-east corner, and belongs to the Moorfoot chain. The Lower Silurians, with their associated igneous rocks, are well developed in Lammermuir, and will be described in the Memoir to accompany Sheet 33.

Upper Silurian.—The Upper Silurian of this Sheet lies entirely within the range of the Pentland Hills, and occurs as three or possibly four separate patches, being repeated by a system of parallel faulting. As has been stated above, these Upper Silurians form the fundamental rocks of the Pentland Hills, and are covered unconformably by the Upper Old Red Sandstone, by felspathic traps of Old Red age, or by Lower Carboniferous Sandstone. That they are now visible is the effect partly of the faults, and partly of the denudation of the superjacent deposits. It is evident also that the present exposure of these Silurians is due in some degree to marked inequalities of the surface which they afforded as a floor for the accumulation of the Upper Old Red Sandstone. Indeed, it appears that during the Old Red period these vertical Silurian shales and grits rose above the level of the water as a group of low islands, round and over which sand and shingle accumulated to form the Old Red Sandstone and conglomerate, and that the present Silurian patches are the tops of some of the more prominent islands from which these deposits have been subsequently bared away.

Of the Silurian areas in the Pentlands, the most southerly and the largest occupies between two and three square miles of the hilly ground at the head of the North Esk and Lyne Water, and lies partly in the county of Edinburgh and partly in that of Peebles. The beds there visible are highly inclined and often vertical, their strike being almost constantly to N.E. or N.N.E., and their general dip to the north-west. By ascending the Esk from Carlops, we make a traverse of these beds at nearly right angles to their direction, and obtain the only continuous section to be seen in this district. The series when thus examined up the stream is an ascending one, as shown in the subjoined section. The lowest beds are green, grey, and reddish shales, with bands of grit and sandstone (**A**) which contain abundant remains of *Dictyocaris*, a large crustacean. These beds extend from where the Silurians first appear to the quarries below the mouth of the second rivulet above the reservoir. As they are at very high angles all the way, the thickness of this portion of them, after making allowance for one or two flexures, cannot be less than 2,500 feet. The quarries referred to have been opened in a band of hard sandstone and quartzy grit (**B**). The lower beds of these quarries contain a shell like *Trochus helicites*, an *Orthoceras*, *Mytilus*, *Orthonota*, *Avicula*, &c. A shaley band in the centre of the large quarry contains *Orthonota amygdalina*, and the hard felspathic* and quartzy grit which lies above this band shows numerous fragments which look like fish-plates along with *Encrinites*, and some obscure bivalves. The thickness of these arenaceous beds is probably about 200 feet. Above them comes a group of olive and brown sandy shales and sandstones (**C**), weathering with a concretionary structure, and usually full of well-preserved fossils. These beds become less concretionary higher up, until about half a mile below the Bore Stane they pass into soft red shale and red sandy conglomerate (**D**), the base of the Lower Old Red Sandstone, which is here overlaid unconformably, as shown in the section, by Upper Old Red and Carboniferous Sandstones. From the middle zone of grit to these red shales there cannot be less than 1,000 feet, so that the entire thickness of Upper Silurian strata visible in this locality is probably from 3,500 to 4,000 feet.

Fig. 1.

Sketch-Section of Upper Silurian Strata in North Esk River.



The geological position of these strata is clearly defined by their fossils to be equivalent to that of the Ludlow Rocks of England. For the list of fossils from this locality, *see* Appendix by Mr. Salter.†

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* This felspathic character occurs in many of the grits of this district.

† Upwards of twenty years ago two *Orthoceratites* were detected by Mr. Maclaren in the North Esk (Geol. Fife and Lothians, p. 203); they have since been named *O. Maclareni*. The richly fossiliferous character of these Silurians was first ascertained by myself whilst mapping the district; and all the fossils enumerated above and in the

Of the other patches of the same series of rocks the largest is that which occurs between Bevelaw and Craigentarrie, on the west side of Black Hill. They consist of shales and hard sandy bands, belonging probably to the lower part of the Esk section. If this be the case there must be a synclinal folding of the Silurians, or more improbably, a large fault below Kitchen Moss and Hare Hill. I found in the ravines south of Bevèlaw, *Graptolites priodon* and *Rhynchonella compressa*, with a *Theca* and some other badly preserved organisms.

Hard shales belonging to the same series occur at Habbie's Howe underlying some ashy strata, and skirted on the north-west side by the felstone of North Black Hill, which has been brought down against them by a fault, No organisms have been noted from this locality. (*See* fig. 25).

The last area of Silurian coloured on the map lies to the west of Warklaw Hill (*see* fig. 3. A) I must state, however, that it has been so coloured only after much hesitation, for no Silurian is there seen. The evidence upon which the decision was made lay in the fact that Warklaw Hill is the lowest felstone of the hills, and as along its north-west side the series of felstones unequivocally lies upon Silurian strata (as from Bevelaw to Craigentarrie), the prolongation of the same pavement was inferred at Warklaw. The space can hardly be occupied by carboniferous strata, unless by the agency of some other fault, of which no trace exists, and there is as little evidence of any underlying Old Red Conglomerate. Following the analogy of North Black Hill, therefore, I have coloured the doubtful ground Silurian.

Lower Old Red Sandstone.—The red shales and conglomerates just referred to as overlying the olive sandy fossiliferous shales of the Upper Silurian I am inclined to regard as the basement beds of the Old Red Sandstone. The grounds of this conclusion have been derived chiefly from an examination of the same group of rocks at Lesmahagow, about 25 miles to the south-west, where a much more complete series is exhibited over a large area.* Unfortunately the regularity of the Esk section is affected by a fault which traverses the north-west flank of the Kips Hills, and intervenes between Deerhope Rig and East Cairn Hill. The effect of this fault is to throw out part of the Upper Old Red Sandstones, their higher portion, or perhaps the base of the Carboniferous being brought down against these Lower Red shales and conglomerates. A further, and perhaps the more important result of the fault has been the tilting up of the depressed beds, so that their angle of inclination is for some way about as high as that

---

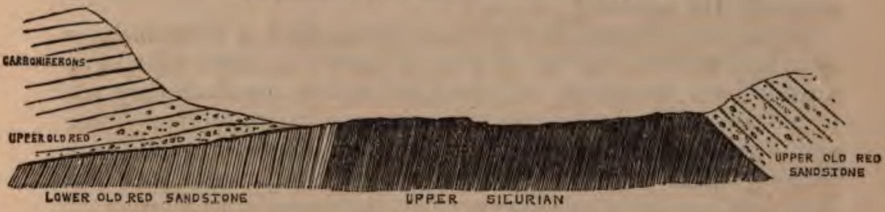
Appendix have been collected by Professor Ramsay, Mr. Salter, Mr. Richard Gibbs, or myself.

* The succession of strata at Lesmahagow was first pointed out by Sir Roderick Murchison in 1855 (*see* Quart. Journ. Geol. Soc., vol. xii. p. 15.) Another memoir on the same district was read by myself before the Geological Society, Jan. 18, 1860 (*see* Quart. Journ. Geol. Soc., vol. xvi. p. 312), in which I have shown that in the Pentlands and at Lesmahagow the Upper Silurian and Lower Old Red form one connected series, while the Upper Old Red and the Carboniferous form another, and that between the two series there is a marked unconformity.

of the Lower Old Red. Hence the unconformity which really exists between the two series of rocks is not so apparent here. When it is remembered, however, that the Lower Old Red and the Silurian form here one consecutive series, and that the Upper Old Red and Carboniferous Sandstones rest in the most violent unconformity upon the Silurian, it will be seen that the same unconformity must subsist between the Upper and the Lower Old Red.* If, therefore, we throw the fault out of the question, the section will be as below.

Fig. 2.

DIAGRAM TO SHOW THE GENERAL RELATION OF THE ROCKS AT THE SOUTH END OF THE PENTLAND CHAIN.



The bearing of these points on the geology of the south of Scotland is of considerable importance. The Lower Old Red shales visible in the Esk are of small extent. They are soft, red, and marly, and have not yet yielded any fossils. Above them comes a set of red felspathic conglomerates, consisting of well-rolled pebbles of felstone, granite, red sandstone, red grit, and quartz of all sizes up to half a foot in diameter, the average dimension being about one inch. Partings of red sandstone occur in these conglomerates, and higher up the stream the conglomerates graduate into red sandstone. The ground then becomes covered with peat and débris, and no rock can be seen for some distance, until after crossing the line of fault we come to some red and brownish grey sandstones, which are evidently an under portion of the East Cairn Hill series, *i.e.*, passage beds between the Upper Old Red and the Lower Carboniferous.

In no other part of the Pentland Hills do strata of Lower Old Red age occur, and were it not for the very clear evidence furnished by the river sections at Lesmahagow we should hesitate to regard the red shales of the Esk as other than a higher part of the Upper Silurian series.

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* See this point more fully discussed in the last paper referred to in the preceding note.

Though these subdivisions of the Old Red Sandstone are used in the present Memoir, it is well to remark that the series of sandstones and conglomerates, here called "Upper Old Red," graduate up in conformable succession into the Lower Carboniferous; while the "Lower Old Red" passes with equal conformity downward into the Upper Silurian. It may eventually be found necessary to adopt the classification proposed by Mr. John Kelly, and elucidated by Mr. Jukes (Text-Book, p. 428 et seq.), viz., that the Upper Old Red forms the basement portion of the Carboniferous series, while the Lower Old Red occupies the upper part of the Silurian.

CHAPTER III.

UPPER OLD RED SANDSTONE.

THE Upper Old Red Sandstone embraced in this Sheet lies entirely along the great central axis of the Pentland Hills. It comprises a thick series of red and green sandstones and conglomerates resting unconformably on the Ludlow shales and grits just described, and graduating upward into the fine conglomerates and sandstones of the Lower Carboniferous series. It contains also a remarkable series of contemporaneous igneous rocks, which form the prominent Pentland chain. A sketch of the geology of these hills, therefore, will best explain the Upper Old Red Sandstone of Mid Lothian.*

Conglomerates and Sandstones of South End of Pentlands.—The fundamental Silurian shales and grits of these hills have already been described. At the south end of the chain they are overlaid by a great thickness of coarse conglomerate, green grits, and sandstones, which rise into rounded undulating hills, extending southwards into Peeblesshire. Although the Upper Old Red dips, on the whole, away from the underlying Silurian, it lies mostly on the south-east side of the anticlinal axis of the hills, while its place on the north-west side is chiefly occupied by the Lower Carboniferous. The cause of this diversity becomes clear when we remember that during the deposition of the Upper Old Red, the Pentlands formed a definite chain, which continued to sink during the progressive formation of the different deposits We must also bear in mind the parallel faults which flank the hills, and by which a considerable thickness of Upper Old Red Sandstone has probably been depressed on the north-west side.

A good typical section of the Upper Old Red strata of the Pentlands may be seen in any of the streams which flow down the east side of the hills, as the Lyne, the Esk, or the Monk's Burn. In the last-mentioned streamlet the following strata are visible, the lowest occurring at its upper end:—

	FT.
Felstone, *of Nine Miles Burn*	800 to 1,200
Felspathic breccia	
Red sandy conglomerates, *with felspathic layers*	
Hard grits, *and* soft green and yellow sandstones, *the whole very generally conglomeritic, but most so towards the base, where there are regular seams of conglomerate*	
Coarse green conglomerate, *of Silurian grit*	100
Grits and sandstones, *as before, conglomeritic*	200
Coarse greenish conglomerate, *of Silurian fragments*	150
Yellow grit *and* sandstone	40
Very coarse red conglomerate	250 to 300
Highly inclined Silurian red shales.	

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* I refer with pleasure to the admirable description of Mr. Charles Maclaren, (*see* his "Geology of Fife and the Lothians," p. 124, *et seq.*,) which, with his survey of Arthur's Seat, will always rank as one of the classics of Scottish descriptive geology. A more extended examination of the district has enabled me to modify his results in several places, but the main facts remain as he traced them nearly a quarter of a century ago.

These thicknesses are only approximative, having been obtained by protracting the angles of dip taken at short intervals in the bed of the stream.

The conglomerates are always coarsest at the base of the series. They consist chiefly of hard grey grits derived from the waste of the underlying Silurians; there are also smaller fragments of quartz, jasper, and various felstones, the last being usually most abundant towards the top. The paste is generally sandy and more or less felspathic, such as would result from a comminution of the grit pebbles; in some places it becomes more argillaceous, and occasionally it consists of white crystalline carbonate of lime. The sandstones and grits have a greenish or grey hue, and are generally markedly felspathic; the felspar being disseminated through them in the form of minute yellow or pinkish grains. In many cases it would be impossible to distinguish some of the harder varieties of these grits from the subjacent Silurian grits, out of which they have probably been in great measure formed. Usually, however, they are softer-grained, flaggy, and false-bedded, with a sprinkling of small rounded pebbles, which increase in certain layers till they form seams of sandy conglomerate. These strata vary of course in details as they are traced even for a short distance, the Monk's Burn section differing from that of the Esk, which in turn does not wholly agree with that of the Lyne. The frequent alternations of sandstone and conglomerate point to in-shore conditions of deposit round a group of low reefs and islets, and since these alternations are characteristic of the whole series from base to top through a thickness of, perhaps, 3,000 feet, it is plain that they were formed during a period when the land of the neighbourhood was slowly subsiding. That subterranean forces were at work in this district during the period of the Upper Old Red Sandstone we have abundant proof in the long series of volcanic products, which now falls to be described.

The highest beds ot the Monk's Burn, as shown in the preceding table, are overlaid by a dark red compact felstone. The section laid open by the next stream to the north-east shows that this felstone, in its lower part, consists of two or three thin beds in reddish sandstone and conglomerate. To the south-west, also, at Patieshill, the same felstone contains a thick lenticular bed of conglomerate and sandstone, while its upper part along the turnpike road is covered by felspathic conglomerates and shattery grits. We can traçe the same rock northward into the Kips Hills, where it swells out into a bed several hundred feet thick. In descending the north slope of these hills into the Logan valley we again come on the base of the felstone, but here, in place of sandstone and conglomerate, it is underlaid by beds of ash and great sheets of felstone. These rise from the other side of the valley into one of the two chains of connected hills of which the central part of the Pentlands consists, while the Kips Hills and their north-eastern prolongations, Scald Law, Carnethy, and Turnhouse Hill, form the other. Although, therefore, in the Monk's Burn and the streams to the southward there is a continuous section from the base of the conglomerates up to the Kips Hill felstone, that section does not represent the geological sequence of the central and northern part of the hills. There we find that the whole of the great conglomerates which form the south end of the chain are replaced by sheets of felstone with narrow lenticular interstratifications of ash, sandstones, and conglomerate. A reference to the map will show how this change is effected. The great conglomerates and sandstones range north-east to the west Kip Hill, but the long Logan Vâlley fault has thrown out such parts of them as may originally have flanked the western side of the anticline. We can see, however, that in their northward progress their thickness becomes greatly less, so much so, that along the top of the ridge at Cap Law they have, perhaps, less than a third of the depth which can be seen in the Monk's Burn. This thinning out towards the north fully accounts for the want of any sandstone or conglomerate between the Silurian and the felstone at Bevelaw. In explication of the appearances here presented we may suppose that during the earlier part of the Upper Old Red Sandstone period in this locality, the conglomerate and sandstone of Spittal Hill and Cap Law existed as a shingly submarine bank by which a series of lava-form ejections flowing from a crater some miles to the north-east were arrested in their progress and diverted eastward. These ejections, with periods of intermission, marked now by the sandstone and conglomerate intercalations, continued until a vast mass of igneous matter in successive sheets was heaped up to the north-east of this bank to form what we now know as the Pentland Hills.

Interbedded Igneous Rocks of the Pentland Hills.*—The igneous rocks of this chain occur as long consecutive sheets of felstone, with occasional ashy bands, dipping south-east at an average angle of 25° to 30°. They are truly interbedded masses in the Old Red Sandstone, seeing that they rest upon the conglomerate and sandstone just described, while between and above them occur bands of conglomerate made up of their fragments. The north end of the hills exhibits considerable confusion in detail, felstones of many different kinds occur there in short lenticular patches, with intervening ashy layers, and it requires some little time to discover that even hêre the general direction of the masses corresponds with that of the entire chain, namely, north-east and south-west. From this more complicated area the larger beds, such as the Kips Hill felstone already referred to, extend to the south-west for six or eight miles, preserving their distinctive characters throughout the whole of their course. The subjoined section exhibits the structure of the hills to the north-east of the conglomerate bank above described.

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* *Interbedded* is used to denote those sheets of igneous matter which have been ejected previous to the deposition of the strata which cover them, but in the same geological period, and which are hence known as *contemporaneous*. There are, however, other parallel sheets which owe their parallelism to injection along the bedding planes of the strata; such masses are called *intrusive* or *subsequent*.

The lowest felstone bed in geological position is that which forms Warklaw Hill (**B** in fig. 3). In its under part it is a hard, blue, compact rock, sparingly porphyritic; higher up it becomes more porphyritic and amygdaloidal, until along its upper surface it is a highly vesicular and porphyritic amygdaloid, the cavities, when filled, containing calcedony, quartz, calcspar, green earth, &c. When seen from the north-east, Warklaw Hill presents an unmistakably bedded contour, the three beds of which it consists dipping S.S.E. at about 20°.

The next bed in ascending order (**C**) forms the eminence on the east side of the reservoir called Torduff Hill. It is a much lighter-coloured felstone than the last, having a pale flesh-coloured tint, dull, often mottled and brecciated, and sparingly porphyritic. Veins of barytes occur along the cliff overhanging the reservoir.

Both of these felstones are overlaid along their southern edges by Lower Carboniferous strata (**C A**). There is a local unconformity in the line of junction, and the beds immediately resting on the felstone are highly felspathic, as may be seen towards the head of the Kenleith Burn. Cherty limestone has been quarried on the south side of Warklaw Hill, and a thin bed may be seen in the strata between the two reservoirs. The shales on the south side of Clubbiedean Reservoir contain *Sphenopteris*, *Myalina*, &c., and they have, therefore, no immediate connexion with the felspathic traps on which they rest. That they were deposited on an uneven surface of these traps is shown partly by their truncation of the Torduff bed, and partly by the protrusion of an outlying mass of the Warklaw bed among the strata south of the Clubbiedean Pond. But these Carboniferous rocks will be referred to again in their proper place in the geological series.

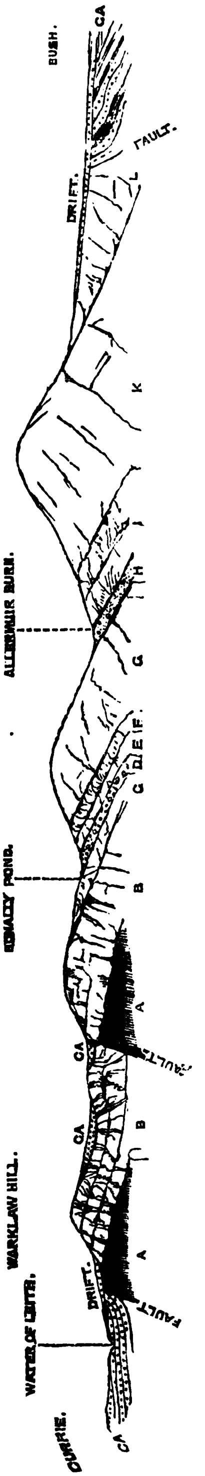

Fig. 3. SKETCH-SECTION ACROSS PENTLAND HILLS FROM CURRIE TO NEAR BUSH.

Reference to the map will show that to the south-east of Torduff Hill there occurs a fault which ranges in a north-east and south-west direction along a considerable part of this side of the Pentlands. Its effect has been to depress the rocks on the west, and throw them for some distance into a vertical or even reversed position. Hence it comes that both Warklaw Hill and Torduff Hill are outliers detached from the main mass of the hills by this fault, for we find them continued on its east side. The peculiar quartziferous amygdaloidal felstone of Warklaw is easily recognizable in the crags of White Hill above Bonally, while the marked flesh-coloured rock of Torduff is not less readily observable, resting above the White Hill bed and stretching eastward to beyond Howden Burn.

At the Bonally pond the pale felstone (C) is overlaid by a thin seam of conglomeritic sandstone (D) of limited extent. Another, but much larger, lenticular mass of conglomerate occurs about the same horizon a mile to the south-west. As exposed on the north-west side of Belld Hill,* it dips south-east at from 45° to 65°, and consists chiefly of well-rounded, green grit pebbles, with a smaller number of yellow felstone, imbedded in a comminuted paste of the same materials.

If we proceed eastward from the Bonally Pond along the Allermuir and Caerketton ridge we cross a succession of felstone beds (as E and F) which, from their variety, frequency, and lenticular character, give an appearance of great confusion to the north end of the chain, and afford some ground for the conjecture of Mr. Maclaren that in this neighbourhood lay the crater of eruption. The changes of mineralogical texture are so frequent that to map out all the varieties of rock here would be almost impossible. The more important masses are given on the map, and for the sake of showing the bedded character of the hills two tints have been used in the geological colouring, the darker marking the darker felstones, such as that of Warklaw; the paler those of a light pinkish colour, as that of Torduff.

Green Craig consists of a dark, compact, porphyritic felstone sometimes almost like a basalt. It rests above the pale felstone of the Howden Burn, and extends northwards to the fault, having been quarried in a round copse near Dreghorn Mains; it dies away southward along the west side of Capelaw Hill. It is surmounted at its north end by another pale felspathic rock, well seen in the next stream east from the Howden Burn. This thins away abruptly to the south for a short space, where the darker beds above and below it unite. South of this point, however, near the head of the Howden Burn, a reddish-white dull felstone (G), like the last, begins and swells out enormously to the south-west, forming the bold chain from Capelaw to Bevelaw. This rock varies considerably in different parts of its course. At Belld Hill it assumes a dull white or yellowish colour, is compact and homogeneous, and weathers with a white surface, its fragments

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*** This name is mis-spelt "Bell's Hill" on the 6-inch maps of the Ordnance Survey.**

strewing the hill sides as long grey lines of rubbish. At north Black Hill it is flesh-coloured, of a semi-hornstone texture, breaks with a clean conchoidal fracture, and is traversed by numerous joints. In the White Cleugh on the south-east side of the hill, the rock assumes a fissile structure, with planes dipping E.S.E. at 23° to 55°. Again, on King's Hill, between Belld Hill and the Glencross Reservoir, the same structure is observable, the laminæ there having frequently a twisted, crumpled appearance. The south-west side of North Black Hill is overlapped by the upper beds of the Old Red Sandstone, as Warklaw and Torduff Hills are overlapped by Lower Carboniferous. The felstone, however, thins rapidly away to the south-west, as may be seen at the north end of Green Cleugh, where the Conglomerate and Sandstone, resting at first on the felstone, soon come to lie directly on the tilted Silurian, which stretches to north-east under the felstone.

Near the bottom of the valley, between Belld Hill and Harbour Hill, occurs another short lenticular patch of greenish grit and conglomerate (**H**). The pebbles are partly of hard Silurian grit and partly of yellow felstone, the paste being strongly felspathic, derived doubtless from the rock of Belld Hill. This bed does not go beyond the south side of King's Hill, and cannot be seen in the next stream to the north, so that its entire length is perhaps less than a mile. In the quarry by the side of the road in Cleuch Maid the dip is south-east at 35°–40°.

The pale felstone, so conspicuous along the west side of the Logan valley, becomes lost towards the north in the confused assemblage of various felstones clustered round Allermuir Hill. Crossing that range, and descending towards the north, we find an irregular lenticular bed of brecciform ashy felstone on the west side of Hare Burn, and again a similar mass on the north side of Shearer Knowe, stretching north-eastward to the road between Swanston and Hunter's Tryst, where it underlies the dark blue compact felstone of Craigside quarry, and rests on the pale mottled felstone which forms the western part of the Braid Hills. The position of this ashy intercalation is indicated on the map.

Proceeding south-west, again, from Allermuir Hill, the next felstone in ascending order that can be clearly traced is a dark compact crystalline rock (**I**),[*] with veins of carbonate of lime and hæmatite. It overlies the felstone and the conglomerate of the Belld Hill ridge, and runs from Allermuir Hill to the Silurian patch at Loganlee, a distance of about 4 miles.

It is overlaid by a continuous band of stratified material marking a pause of some duration in the series of eruptions. The band is first seen in the Allermuir Burn, rather more than a furlong up from the reservoir; it skirts the south side of the reservoir and thence runs along the south-east side of the valley to the Loganlee Reservoir where it is well displayed, especially along the side of the roadway. It continues in a south-west direction across the burn descending from Scald Law until it is cut off by the fault. Throughout this course it varies greatly in composition. In the Allermuir Burn it is a bed of conglomerate resembling those already described; at the Glencross Reservoir it consists of interstratified sandstones and conglomerate, while at the Loganlee Reservoir and in the Scald Law Burn it passes into a felspathic ash, well bedded and interstratified with bands of felstone. As the Loganlee section is complete and easily accessible, and affords besides some important insight into the structure of the Pentland Hills, I shall here give its details, beginning at the bottom :—1. Silurian shales and grits on which the felstone (2) of North Black Hill rests; 3. Dark felstone (the lower part of **x** in fig. 3); 4. A dull yellowish stratified felstone or claystone, the layers ranging from less than half an inch to fully 2 feet in thickness and dipping S. 40° E. at 22°–25°; 5. Well-bedded felspathic ash, some of the beds containing fragments of various felstones, others without lapilli, and closely resembling the subjacent beds 4; 6. Another felstone like some of the thinner bands in 4; 7. Yellowish white felspathic ash like that below (the beds 4–8 occupy the position of the dark line in **x**, fig. 3); 8. Dark amygdaloidal felstone. The section in Scald Law Burn differs from that of Loganlee in the greater relative thickness of its stratified felstones, and in having at the base of the series a dark red micaceous sandstone, about 6 feet thick.

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[*] This and the next felstone bed are not separable where the section (fig. 3) crosses; southwards, however, they are divided by an intercalation of sandstone, &c, marked by the line at **I** in the figure.

Starting again from Allermuir Hill, the next bed in ascending series is a dark compact felstone (upper part of **x** in fig. 3), like that underneath the ash and sandstone band just described. It extends from beyond Allermuir Hill to Kips Hill, thence it trends south-east to Quarrel Burn and onward to Carlops, a distance of about 10 miles. On the west side of Castle Law Hill it is a compact blue crystalline rock, but southwards it becomes highly amygdaloidal and vesicular, forming in this state the two prominent peaks of the Kips Hills. On the west side of the west Kip the felstone rests on the great conglomerate bank already described, all the subjacent felstones and other interstratifications having thinned away. The bottom of the bed in the Quarrel Burn presents some interesting alternations with conglomerate.

I have spoken of this felstone as one bed, from the impossibility to trace it out into more; but in reality it is the product of several eruptions. This is made evident by the occurrence in it of two intercalated sheets of conglomerate, one lying at the head of the Eastside valley, the other at Patieshill, near Carlops. The fault at the latter locality has brought down this conglomerate and its contiguous felstones against the older conglomerates of Spittal Hill.

The upper surface of the felstone (**x**) is, at different places, covered with ash or conglomerate. At Carlops it has a capping of coarse irregular conglomerates and grits, the whole highly felspathic, and some of the beds hardly distinguishable from some of the more granular felstones. At the road north of Walstone the covering is of fine grained felspathic ash; on the west side of South Black Hill it is a lenticular bed of conglomerate, consisting of rounded and subangular felspathic fragments of all sizes up to a foot in diameter, embedded in a granular felspathic paste. Along the north-west side of Scald Law the felstone is overlaid by beds of ashy felspathic sandstone, dipping south-east at 22°.

The felstone (**K**) which covers these sedimentary intercalations forms the highest summits of the Pentland chain, and extends in unbroken continuity from Caerketton Hill to Walstone, a distance of 7 miles. Its base has often a brecciated ashy appearance, as is well seen on the west side of Caerketton Hill; but the main mass of the rock is dull, compact, sometimes like a hornstone, but oftener with a meagre earthy touch. It has a pale whiteish grey or pale pink colour, and the bleached lines of débris which cover the hill sides sufficiently point out its position even at a distance. Towards its south end, in the detached rounded eminence called Broad Law, it has a tawny colour and a strongly vesicular structure concentrically mottled. Its upper surface has a brecciated ashy layer like that on which it rests. This is well seen on the top of Caerketton Hill, where some remarkable interveinings of different coloured felstones occur; it is visible also on the road side at the south end of South Black Hill. From that point the great felstone of the hill begins to thin away rapidly, until at Walstone, the ashy seam below unites with that above, and the felstone disappears.

The rock which forms Scald Law, Carnethy, and Castle Law Hill is surmounted by a series of dark porphyritic and amygdaloidal felstones (**L**), which range north-east from Walstone and form apparently the eastern and larger part of the Braid Hills. Though coloured on the map as one band from the want of continuous lines of demarcation, this mass of rock undoubtedly consists of several beds. Thus at Walstone the rock visible is a well-marked porphyry; on the south-east side of Carnethy it is very compact and crystalline, with small granules of amethyst and large tabular felspar crystals; at the east end of Hillend Hill it is dark red, crystalline and finely porphyritic, while a short way higher up in the series it becomes strongly amygdaloidal, containing kernels of quartz, calcedony, and green earth. In the lower part of the same hill a similar red felstone has its numerous slicken-sided joints coated with serpentine. Passing northwards along the same line we find the felstones of the Braid and Blackford Hills presenting in some places a very compact homogeneous texture as clinkstones, while in others they have a dull, somewhat earthy, and porphyritic texture. Although, therefore, no lines can be traced separating these rocks into distinct beds, they form, as a whole, a well defined band resting on the pale-coloured felstone of Scald Law and Carnethy, and on a similar pale mottled felstone forming the wester Braids.

In fine, the truly bedded character of all these felstones, their interstratifications of sandstone, conglomerate, and ash, and their undoubted place in the Upper Old Red Sandstone, indicate that in the later part of the Old Red period volcanic agencies were long and actively at work in Mid Lothian. The fact, too, that these rocks are covered by conglomerates and sandstones graduating upward into those of the Lower Carboniferous series shows that these agencies had become quiescent here before the commencement of the Carboniferous period.

The upper conglomerates, forming the gradation into the Carboniferous group, occur on the east side of the hills at Liberton and on the west side at Habbie's Howe; their nature and their passage into the superincumbent strata are detailed in the next chapter.

CHAPTER IV.

BASEMENT BEDS OF LOWER CARBONIFEROUS GROUP.

THE long parallel faults by which the Pentland Hills are bounded materially retard any attempt to ascertain the thickness of the great mass of sandstones and conglomerates forming the passage beds or neutral ground between the Old Red Sandstone and the Lower Carboniferous. It is not certain that the whole of that series now reaches the surface, nor that, if it does reach the surface, we have not parts repeated by the faulting. Making due allowance, however, for either alternative, the repetition or imperfection in the series is probably not of any great extent, if the sections be taken north of the Pentlands, since a gradual ascending series can be traced from the Braid Hill felstones up through the Upper Old Red Conglomerate of Liberton, into a series of pale calcareous sandstones and pebbly conglomerates, which form the base of the Lower Carboniferous group, and extending northwards by Craigmillar, re-appear at the Castle Rock of Edinburgh. From this point the series can be traced in ascending order eastward through the central ridge of the Old Town and the rocks of Arthur's Seat. In this section there occurs of course one marked break. One of the larger faults (which, however, is thinning off to the north-east,) intervenes between the Castle Rock of Edinburgh and Craigmillar, so that it is only from their lithological aspect, and from the general structure of the district, that we conjoin the higher part of the Craigmillar beds with the strata at the Castle Rock. In a country so broken and shattered, and so obscured by superficial accumulations, the geologist cannot hope for minute accuracy, and must often content himself that his scattered facts and isolated observations be linked together by what he regards as at best only plausible conjecture.

The highest of the Braid and Pentland Hill trappean rocks are succeeded at Liberton by a coarse, well-rounded conglomerate, lying at the top of the Old Red series, and consisting mainly of felstone pebbles, imbedded in a felspathic and occasionally crystalline calcareous paste. Similar conglomerates, and of the same age, occur also on the south-west side of the hills at Habbie's Howe and along the western flanks of the Kipps Hills. There they are interstratified with red sandstone and one seam of cornstone, the whole passing up into a great series of Lower Carboniferous red and reddish-white sandstones, which, from Hare Hill, extend south-west into the Cairn Hills. To the development of these Lower Carboniferous strata to the west of the great Pentland ridge I shall have again to refer.

The Liberton conglomerate becomes finer as, in ascending succession, we trace it to the north. In the fields to the north of the village the rock comes to the surface in a few irregular knolls, which consist of a pebbly calcareous conglomerate, formed mainly of small fragments of a greyish-white cherty limestone, along with various felstones and grits. From this point higher strata can be seen at intervals towards Arthur's Seat. They are well exposed in the grounds of Kingston Grange, where they consist of gritty sandstone and fine conglomerate, and where also the effect of the long fault can be readily seen, since in the stream the mountain limestone bands are thrown down vertically against these greatly lower and almost horizontal beds. The same low series can be traced, in its upward progress, into the fields of Craigmillar, where, especially at the Castle, the calcareous and pebbly conglomerates are admirably exhibited. Some quarries north of the ruin likewise display some of the finer-grained sandstones. Proceeding still further to the north, we notice at intervals along the road side an ascending sandstone series, until the ground sinks into a drift-covered valley where no rock can be seen. It is observable that in the whole of the series just described (that is, the basement beds of the Lower Carboniferous group,) there is no dark shale visible. Some of the sandstones have, indeed, a finely laminated aspect, and crumble down under the influence of the weather in a manner analogous to that of many shales; there occur, also, red argillaceous beds; but of the dark fissile shales, so characteristic of higher parts of the great Lower Carboniferous group, there occurs among the Liberton and Craigmillar beds not a trace.

Reference to the map will show, as just stated, that between the Craigmillar series and that of Arthur's Seat one of the long faults intervenes. As the effect of that fault is to bring down the strata along its north-west side, we must seek for the continuation of the Craigmillar beds, not in Arthur's Seat, but to the west. Passing westwards, therefore, the only available point of connexion is along the south-east side of another marked fault, which, traversing the west flank of Warklaw Hill and Craiglockhart, and keeping nearly parallel to the Water of Leith, passes under the east front of the Castle Rock. The section at the latter eminence is the only one in the district which seems, in a general way, to piece on to the section at Craigmillar. The sandstones and greenish sandy shales there visible have long been well known to geologists. Their dip is easterly, and in a series of deep drains cut a few years ago along the street leading from the Castle to Arthur's Seat, the series of sandstones and reddish and greenish shales was found to continue down to near Holyrood, having the same general eastern inclination. Hence the Old Town of Edinburgh stands on a series of Lower Carboniferous Sandstones and marly shales, of which the lowest visible portion occurs at the Castle and the highest at Salisbury Craig and Arthur's Seat.

The strata at Salisbury Craig clearly indicate a higher stratigraphical position than those at Craigmillar. The green and reddish hue in the sandstones still remains, but the beds are thinner, more sparingly conglomeritic, and contain numerous thin alternations of green and red argillaceous shale, with some bands of coarse limestone. In the quarries above the greenstone of the Craig the sandstones are well exposed, many of their surfaces showing ripple-marks along with the bores of annelids. On the east side of the Hunter's Bog these strata pass under the volcanic rocks of Arthur's Seat. Before entering upon the latter, however, it may be well to notice the development of the basement beds of the Lower Carboniferous group in other parts of the area embraced in the present Sheet.

When the Lower Carboniferous rocks of Edinburghshire began to be formed the trappean ridge of the Pentlands had not wholly disappeared beneath the Old Red conglomerates and sandstones. Hence in several parts along the western flank of the hills, notwithstanding the long parallel faults, we find different horizons of the Lower Carboniferous series resting directly upon Upper Old Red felstones, and in other parts graduating downward into a diminished series of Upper Old Red conglomerates and sandstones, which in like manner rest at different levels upon the felstones and on the underlying highly inclined Silurian strata. In the streams to the east and south of Warklaw Hill, a series of sandstones, shales, and thin limestones occurs, which possibly represent the similar strata overlying the traps of the Calton Hill; at least they appear to be higher than the sandstones and shales of Arthur's Seat. They rest directly upon the felstone of Warklaw Hill, and from the felspathic character of their lower beds appear to have been derived from the waste of that rock. The floor on which they were deposited must have been somewhat uneven, for about midway up the burn that descends into Clubbidean Reservoir from the south, a mass of the same felstone protrudes from beneath the enveloping strata.* These shales and sandstones contain *Sphenopteris affinis*, *Cypris* (the Burdie House species), *Spirorbis* (two species), *Myalina*. Although probably much modified by the effects of the adjacent fault, the valley of the Clubbidean Reservoir seems to have existed as a sheltered bay during the time when these beds were forming, and the deep gorge between the two reservoirs has been subsequently excavated. A similar bay must have indented the south side of Black Hill and the western flanks of the Kipps Hills long before the erosion of the deep valley of Loganhouse, which now divides the Pentlands into two ranges. The Upper Old Red sandstones and conglomerates at Habbie's Howe accumulated in that bay, and eventually also the earlier part of the Lower Carboniferous group. In short, at the close of the Old Red Sandstone, and during the earlier part of the Carboniferous period, the long ridge of the Pentlands was being slowly submerged. The western outline of the ridge was sinuous and indented, and perhaps the eastern flank presented a similarly varied contour. But all these inequalities were eventually silted up, and long before the end of the Lower Carboniferous sandstones the whole ridge had finally disappeared beneath the growing sediments. If the observer wishes to have ocular proof of these facts, let him ascend the rock-strewn sides of East Cairn Hill, and standing on the almost horizontal sandstone beds on the summit, 1,839 feet above the sea, let him carry his eye northward and mark how completely these strata if prolonged would sweep across the Pentlands. Let him note also, as indeed in the ascent he could not fail to do, how striking are the proofs, in this hill, of enormous denudation. The truncated ends of the gently inclined strata can be traced above each other among the furze and the scattered blocks, upward from base to summit like tiers of masonry. The Cauldstane Slap—a deep defile between the two Cairn Hills—has been cut down through these sandstones fully 500 feet. Everywhere, indeed, the proofs of powerful denudation are apparent, and when the observer marks how well the thickness of beds still left at Cairn Hill would, if prolonged, cover over the heights to the north-east, he can have little doubt that the mass of superior strata which has been swept away, must have risen high over even the highest summits of the Pentland Hills.

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* *See* ante, fig. 3, p. 11.

Trap Rocks of Arthur's Seat, Calton Hill, and Craiglockhart.—It was probably after the entire submergence of the Pentland ridge that the volcanic rocks of Arthur's Seat, already referred to, began to be ejected. From this point in the chronology, the geology of Mid Lothian becomes more defined and varied. We begin to detect more frequent varieties in the character of the sedimentary material, traces of plants become more common, and soon abound, the fauna likewise increases rapidly, while at irregular intervals there occur marked evidences of volcanic action.

In order to understand the trappean geology of Arthur's Seat and the neighbourhood of Edinburgh, it is necessary to attend somewhat carefully to the system of faulting, and also to the extensive denudation of the area. The axis of the great Carboniferous anticline, after traversing the line of the Pentland Hills, continues through the town of Edinburgh, and gradually disappears towards the north. Hence the strata on the east of the town dip eastward while those on the opposite side dip west. If, therefore, no faults intervened, we should find the same strata on both sides, and the Arthur's seat series would thus be repeated somewhere about the site of Donaldson's Hospital. This regularity, however, does not exist. A reference to the map will show that one of the Pentland Hill faults crosses on the east side of the Castle Rock. Its effect has been to throw below the surface on the west the whole series of reddish sandstones and shales between the east end of Arthur's Seat and the Castle, and to bring a set of dark shales, forming the lower part of the well-known Wardie series, down on a level with the greatly lower beds at the Castle section. This fault is well shown on the east side of the rock below the Half Moon Battery; the strata are there bent and broken, and the hard basalt is grooved by the friction of the rock masses.* It is impossible to ascertain exactly the amount of displacement here; if, however, the strata continue to dip steadily eastward at an average angle of only 15° (and this supposition is certainly not over the truth,) then the shales to the west of the Castle must have sunk down not less than 2,500 feet. It is very evident, therefore, that the strata west of this fault belong to a higher part of the series than those of Arthur's seat, and that consequently we cannot expect to find the latter prolonged to the west.†

Since the Castle fault, however, does not coincide with the anticlinal axis, but traverses it obliquely from south-west to north-east, we find the axis, irregular, indeed, but apparently unbroken, between that fault and the next one to the south-east. Traces of the arching of the strata, though scanty enough, can yet be seen at several points among the southern suburbs. In an old quarry near the Grange Cemetery, red sandstones, evidently very low in the series, dip slightly west of north. Here the dip seems just on the point of turning westward, while when we pass west to Bruntsfield Links we find the north-west dip confirmed, whence it continues the prevailing direction for four or five miles south-westward to Warklaw Hill. It is with this reversed dip that the trappean rocks of Craiglockhart are inclined. Viewing these rocks in connexion with the physical structure of the district, and with the lithological features of the strata, among which they occur, it seems far from improbable that though now disconnected by denudation these rocks were once continuous with those of Arthur's Seat. I am thus particular in pointing out the probable extension of the volcanic series of Arthur's Seat, in order that before entering upon the detailed structure of that hill the reader may bear in mind that though these volcanic materials, now only exist in scattered patches, they must once have covered a much greater area, and are therefore more important than their present local character would seem to justify.

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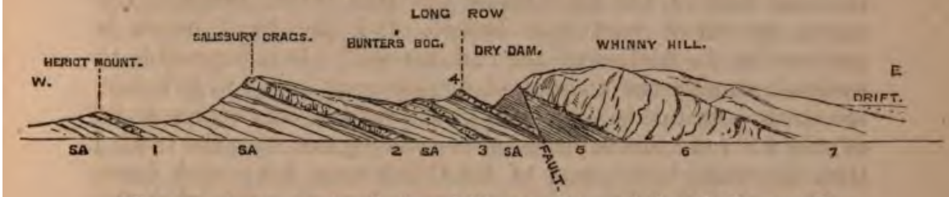
* This grooving on the side of a fissure is technically known as "slickensides."

† For further remarks on the Pentland Hill faults, *see* Chap. xii.

Arthur's Seat.—In investigating the structure of a trappean district it is desirable to ascertain which of the traps are contemporaneously *interbedded* with the rocks wherein they occur, and which are *intrusive*, i.e., later than the rocks they traverse. Fortunately in the case of Arthur's Seat this determination can easily be made. There the lowest three greenstones are intrusive, and occur together, leaving the eastern side of the hill to be considered by itself as a series of contemporaneous masses in the Lower Carboniferous series.*

Fig. 4.

SECTION THROUGH NORTH END OF ARTHUR'S SEAT.



The western part of the hill consists of (**S A**) Lower Carboniferous sandstones, bands of fine conglomerate, shales, and impure limestones, dipping east at from 17° to 30°. These rocks are well displayed along the mural cliffs of Salisbury Craig and in the quarries above the Hunter's Bog. The sandy beds are sometimes ripple-marked and covered with annelid burrows, while fragments of carboniferous plants occasionally occur in them. They contain the three beds of intrusive trap just mentioned.† Of these, the lowest is that of Heriot Mount and St. Leonard's Craig (1), a hard blue greenstone with disseminated crystals of felspar, but towards the top more compact in texture and very sparingly porphyritic. It forms the crest of the ridge running in a semicircular line from Dumbiedykes to near the Hawse, where it joins the greenstone of Salisbury Craig to form the thick mass of Samson's Ribs. It is both surmounted and underlaid by red and white altered sandstones, which can be seen in the quarries at the east end of Beaumont Place, in the cutting of the Queen's Drive, opposite the gate at the railway tunnel (where the overlying strata are greatly altered), and in another cutting at the Hawse. At the latter locality, the rocks visible are in some of the beds highly conglomeritic and calcareous, numerous fragments of cherty limestone occurring in a calcareous sandy base. There is no rock seen in place up the steep western acclivity of Salisbury Craigs; there seems little doubt, however, that the herbage and débris conceal strata similar to those which occur both at the top and bottom of the greenstone cliff.

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* The rocks immediately round the summit, as I shall show in a subsequent chapter, have no connexion with the Carboniferous traps, but belong to a much later geological period. (*See* Chap. xiii. and fig. 25.)

† It seems desirable here, for the sake of local connexion, to describe these intrusive greenstones in this part of the Memoir, although they ought to be placed in the section devoted to INTRUSIVE TRAPS.

The next bed of intrusive greenstone in ascending order is that which forms the semicircular mural escarpment of Salisbury Crags (2). Like the last, it is a compact blueish grey granular rock, containing carbonate of lime, prehnite, and other minerals. Its under surface is well shown along nearly the whole extent of the pathway which skirts the cliff, and on the south side some interesting sections are exposed (*see* fig. 19). Both the trap and the strata on which it rests become altered within a foot or two of the point of junction; the sandstones are converted into a kind of quartzite, the shales acquire a jaspideous character, while the trap becomes much finer grained, and has a dull red colour.* The junction of the upper surface of the greenstone, with the superincumbent strata is not less interesting. It can be well studied at the north end of the Crags, where the beds resting on the trap will be found to be considerably altered, showing that the igneous rock has been thrust in below them, and is consequently an *intrusive* trap. Further proof of this intrusive character occurs at the southern entrance to the Hunter's Bog, called the Hawse. There a seam of shale, very much hardened and broken, lies completely enveloped in the greenstone, while one or two masses of smaller size are similarly enclosed and traversed by innumerable veins of greenstone (fig. 19). But, perhaps, the most satisfactory evidence as to the intrusive character of this and the subjacent greenstone is be found in the fact that while along the west side of Salisbury Craigs, the two beds are separated by at least 700 feet of stratified rock, they gradually approach each other towards the east, cutting across these strata obliquely, until, as above mentioned, they become united at Samson's Ribs into one thick mass of columnar greenstone. In following the Radical Road round Salisbury Crags, the observer will notice two conspicuous greenstone dykes cutting through the greenstone of the cliffs; one at the highest part of the crag, the other nearer the north end. The first-mentioned can be traced for some distance down the eastern slope of the Crags.

The third greenstone (3) in ascending series is that which forms the irregular chain of knolls, called the Dasses, rising along the eastern side of the Hunter's Bog. It is a highly porphyritic greenstone, the felspar crystals on weathered surfaces being white and the base greenish, a feature which renders it easy of detection on the south side of the hill where, as a prominent crag, at the west end of Duddingstone Loch, it re-emerges from under a vast mass of later volcanic material. The intrusive character of the Dasses is very apparent. The ridge consists of several lenticular sheets of greenstone inserted irregularly among highly altered sandstones and shales. A short slope analogous to that on the west side of Salisbury Crags, and probably covering similar sedimentary rocks, rises eastward from the Dasses, and is surmounted by a long regular bed of rudely columnar greenstone, called the Long Row.

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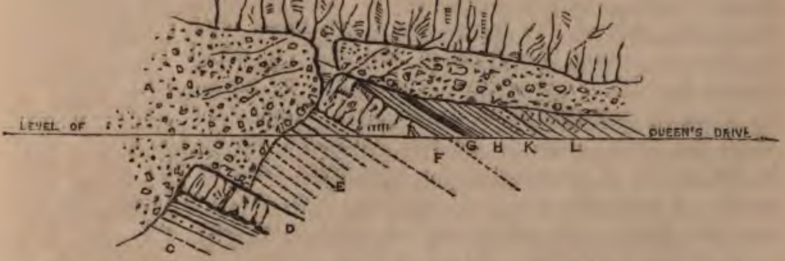
* This difference in texture undoubtedly arose from the cooling of the heated mass; but the change of colour may possibly be something long subsequent, and due to a process of oxidation extending inwards from the point of contact with the red ferruginous shales.

The rock of the Long Row (4) forms the oldest of the contemporaneous greenstones. It is very black, compact, approaching a basalt, with scattered crystals of angite and amygdaloidal nodules. From this point upward we have an ascending series of Lower Carboniferous traps, the horizon of which is definitely marked. These, however, do not embrace the whole of the rest of the igneous rocks of Arthur's Seat. A reference to the map will show that round the summit of that hill is grouped a set of ashes and basalts, which have no connexion with the rest, but repose unconformably upon them. The area embraced by these later rocks is well defined by the contour of the hill. It extends westward from Dunsapie Loch to the Hunter's Bog, including the whole of the higher part of the hill that lies between the head of the Dry Dam and the Queen's Drive. As this area falls to be described in a subsequent section it is omitted here, and the reader will in the meantime consider it as a great volcanic cake laid down upon the upturned edges of the Carboniferous series. I have just shown that the intrusive greenstone of the Dasses extends below this cake, and re-appears on the south side. The same is the case with the Long Row. We find it forming the eastern of the two crags of Duddingston Loch, and ascending the slope to the Queen's Drive, where it plunges below a mass of volcanic conglomerate and basalt. The strata (5) by which the greenstone of the Long Row is overlaid can be seen at two places,—in the section at the Queen's Drive and along the east side of the green valley called the Dry Dam, which extends southward from St. Anthony's Chapel. At the former locality the following section is visible.

Fig. 5.

SECTION ON SOUTH SIDE OF QUEEN'S DRIVE.



A is the mass of later ash covering the Carboniferous beds unconformably, and overlaid by the basalt of the Lion's Haunch (**B**); (**C**) the sandstones, &c. below the lower greenstone, not seen at the point of section; (**D**) greenstone (= the Dasses, marked 3 in fig. 4); (**E** sandstones, &c. not seen at point of section; (**F**) greenstone of Long Row, 4 in fig. 4; (G) red nodular ash, about 3 feet; (H) red ashy sandstone, in thin bands, with marly partings; (K) white cherty limestone seen in blocks above the roadway, and probably overlaid by a few feet of sandstone; (L) green felspathic ash of the Dry Dam. At the north end of the Dry Dam part of these strata can be seen again, though the section is much covered. Immediately south of the crag on which St. Anthony's Chapel stands we find some whitish sandstones, below which the upper surface of the Long Row has in places a markedly ashy aspect, while a short way above, a well-bedded green felspathic ash forms the higher part of the slope along the east side of the valley immediately under the crest of basalt. Two faults cross the east side of this valley, the effects of which are shown on the map. The most southerly merely depresses the beds on the east side of the Dry Dam, and does not cross the Long Row, while the other cuts across valley and crag, throwing a part of the Long Row westward, as a detached eminence called Haggis Knowe, and depressing the basalts from the top of the eastern slope of the Dry Dam to the bottom.

The ash (5 in fig. 4) of the Dry Dam is one of the most characteristic igneous products of the hill. It has a distinctly bedded structure, some of the beds being even fissile, but its texture varies considerably in the different beds, and even at a short distance in the same bed. Some of the strata consist of an agglomeration of rounded and subangular lapilli of various sizes up to that of a nut, with occasional larger rounded fragments. Others are much finer grained, consisting of a dull grey or greenish felspathic paste, with rounded balls of greenstone a foot or less in diameter. The character of the imbedded fragments is eminently trappean; a few pieces of sandstone or hardened shale and occasional irregular nodules of cherty limestone may be detected, but by far the greater number are pieces of greenstone, basalt, or felstone in a comminuted felspathic paste. About midway down the valley of the Dry Dam we find in this ashy series a short lenticular bed of basalt, and another bed of highly amygdaloidal greenstone occurs near the same spot, but higher up on the slope. At the lower end of the Dry Dam, on crossing to the north side of the larger fault, we meet with a continuation of the ash along the front of the cliff on which St. Anthony's chapel stands. It is there surmounted by basalt, and underlaid by a highly amygdaloidal greenstone, which itself probably rests upon the main mass of the ash concealed under the green slope to the west. This greenstone resembles that in the ash further south; it contains grains of specular iron, veins of hæmatite, and cavities filled with carbonate of lime, calcedony, &c. The ashy beds at St. Anthony's chapel resting upon this greenstone are dark, shaly, and carbonaceous, with remains of Lower Carboniferous plants and scales of *Rhizodus*, &c. They thin out towards the north, and do not reappear after the greenstone below them and the basalt above unite. If now we cross the mass of later unconformable rocks forming the upper part of the hill we shall find the same ash reappearing on the south side in the section at the Queen's Drive, as is shown in fig. 5. The depth of soil and herbage below the roadway prevents us from tracing the rock downward towards Duddingston Loch, but as the greenstone below and above it stretch southward as far as the loch the ash probably does so too.

The ash now described cannot be confounded with that which occurs in the upper unconformable series, and in proof of this the observer, after studying carefully the rocks of the Dry Dam, should cross the hill, and, proceeding along the Queen's Drive westward from Dunsapie, examine the section there laid open. The first rock visible is the green ash just referred to, which exhibits precisely the same features as its prolongation in the Dry Dam. Below this he will meet with the strata given in fig. 5, and at the point where the greenstone bed crosses the road he will observe the later ash or volcanic conglomerate wrapping round the truncated ends of these beds, and presenting an irregular unstratified tumultuous aspect totally unlike the regularly bedded character of the older ash.

The ash of the Dry Dam is surmounted by a bed of black columnar basalt (lower part of 6 in fig. 4), containing granules of green serpentine. It lies as a regular bed towards the south end of the valley, but towards St. Anthony's Chapel its position becomes obscured, although it reappears in the detached crag on which the ruin stands, and rests there on the plant-bearing shales described above. Above the basalt comes another having an amorphous aspect and a chocolate colour. This is succeeded by a basalt of the more regular type; but these beds cannot be satisfactorily traced throughout the range of eminences which rise along the eastern side of the Dry Dam. They coalesce with each other, more especially towards the north, where, in the steep cliff behind St. Anthony's chapel, the rock becomes highly amygdaloidal, like the greenstones in the lower part of this series. These are not intrusive traps, they are truly contemporaneous sheets ejected at successive intervals over the sea-bottom during the Lower Carboniferous period. We can trace them southwards to Dunsapie, of which they form the lower and larger part, and thence down the slope to Duddington Loch. A continuation of the same series forms the western and lower part of the Calton Hill rocks, which are separated from those of Arthur Seat by a powerful fault running along the valley traversed by the railway. Along the steep escarpment on which the Calton gaol stands, and on the eastern side of the roadway below the Regent's Arch, the lower greenstones and basalts of the Calton Hill may be seen so similar in aspect, and in the character of the rocks covering them, that we cannot doubt that they form a part of the Dry Dam series.

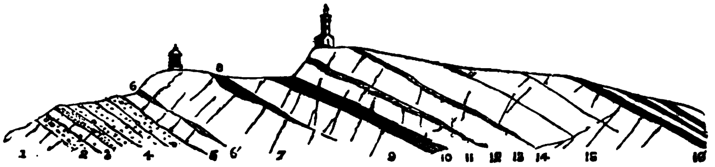
The basalts and greenstones (6) which thus overlie the ash of the Dry Dam, and extend from Duddingston Loch to the north-west side of the Calton Hill, are surmounted by a group of porphyritic and amygdaloidal felstones (7), which form the remainder of the eastern part of Arthur's seat from the top of Dunsapie across the series of knolls forming Whinny Hill to the railway station at St. Margaret's. They likewise constitute nearly the whole of the Calton Hill. Although in traversing Whinny Hill from west to east we pass over several alternations of rock undoubtedly marking successive beds, the changes are so gradual and so irregular that it is hardly possible actually to map the varieties. At the south end, near the head of the Dry Dam, some of the basalts last described may be seen much altered in texture and aspect, and gradually passing upwards into porphyritic felstones. A good section of the felstones is seen at the north end of the hill, where they have been cut in the process of making the Queen's drive. Some of the beds there visible are highly amygdaloidal, the cavities being filled with green earth, calcspar, or calcedony, but often empty. Others are more compact, and contain numerous felspar crystals and grains of specular iron. The highest bed seen here is that which occurs at the park wall south of the Garden of Parson's Green, and another exposure of perhaps the same bed occurs within the St. Margaret's station, where the rock presents a well-glaciated surface. The felstone at the latter locality deserves attention from its close resemblance to the highest visible bed on the Calton Hill. Before describing the structure of that hill, I shall here adduce the proofs independent of their internal agreement, that the Whinny Hill of Arthur's Seat and the Calton Hill are not independent masses of trap, but must at one time have been united.

It cannot be denied that comparing the two hills where they look towards each other, they have each a truncated aspect. The Calton Hill plunges down steeply into the valley of the railway, Arthur's Seat also descends abruptly into the low ground to the north. In either case we find that this truncation of the contour does not arise from any peculiar disposition of the rocks, such as the bedding of greenstones among sandstones, which has produced the escarpment of Salisbury Crags, but that the steep slope in both hills cuts at nearly right angles across the bedding. Moreover, if we try to trace the felstones of Whinny Hill and St. Margaret's northwards, or those of the Calton Hill southwards, we shall discover that while in the former instance no evidence can be obtained, owing to the depth of drift, in the latter the felstones are abruptly replaced by sandstones and shales of the Lower Carboniferous series. This was admirably shown a few years ago in cutting a deep drain down the whole length of the Canongate, where, with the exception of three or four small dykes of greenstone, the whole of the rock traversed was reddish sandstone and marly shales. It follows, therefore, that the Calton Hill is only part of a larger series, and that its southern side has been truncated by a fault. The missing portion is not far to seek; it undoubtedly forms the eastern part of Arthur's Seat; there is no similar mass of trap for miles around, while the two hills agree as closely as we can expect trappean material to do. They have each a lower series of contemporaneous basalts and greenstones, covered by a group of resembling felstones. Those felstones at the Calton Hill are separated by several ashy layers, which I have not detected on the eastern part of Arthur's Seat, but the latter locality furnishes no such complete sections as the former, and there consequently may be similar layers in some of the lines of green valley, between the felstone beds of Whinny Hill. But even should there be none, this circumstance, as I shall afterwards have occasion to show, is fully explained by the markedly local character of the ash beds which occur in the Carboniferous series of the Lothians.

Calton Hill.—This hill, as already stated, consists of various felstones with ashy interstratifications, resting on a dark angitic rock, and surmounted by shales and sandstones. The following figure gives a detailed section of its structure along a line passing nearly east and west through the highest part of the hill. It must not be supposed, however, that all the beds here enumerated are continuous; on the contrary, it is impossible to trace some of the ashy seams for more than a few yards, and if they are so inconstant here, we can readily understand how they should not extend into Arthur's Seat. The lowest bed (1) is the angitic rock already referred to, which forms the escarpment at the gaol, and corresponds to the basalts and greenstones of St. Anthony's Crags; (2) green and reddish fine-grained nodular ash, seen behind the Calton Convening Rooms; (3) yellowish green earthy felstone; (4) coarse irregular ash, full of felspathic bombs, seen in ascending the stairs opposite the gaol; (5) light grey porphyritic felstone, becomes vesicular atop; (6) shale, with rounded felspathic nodules, becomes red and ashy towards the east, seen on western pathway; (6^1) a small lenticular patch of ash on the same horizon as the last; (7) light purplish grey or greenish poryphyritic felstone, crystals of felspar and specular iron are abundant; it closely resembles 5, and towards the top becomes darker red and very vesicular; (8) fine-grained stratified red felspathic marl, with rounded fragments of different porphyries, in a thin lenticular patch like 6; (9) strongly amygdaloidal porphyritic felstone, cavities filled with calcspar, hæmatite, or green

Fig. 6.

SKETCH-SECTION OF CALTON HILL.*



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* In this figure the engraver has taken some liberty with the architecture of Nelson's monument, but as an Edinburgh reader will admit, his rendering is hardly less artistic than the reality.

earth; the felspar crystals are very abundant in places, and the weathered surfaces highly vesicular; (10) stratified red felspathic sandstone, with beds of hard, compact ash,* which contains angular fragments of felstone, and are partly made of felspar crystals, many of which are broken and some rounded; (11) compact yellowish green felstone, abundantly porphyritic; (12) greenish-purple, dull, felspathic ash, containing numerous rounded felspathic balls of every size up to 1½ foot in diameter; this bed may be seen in the cliff on which Nelson's monument stands, descending to the roadway at the back of the High School; (13) light greyish-purple compact felstone, porphyritic, and with irregular cavities of calcspar; (14) stratified ash, made up of pinkish felstone fragments and broken crystals of felspar in a felspathic paste; a little below on the road behind the High School it becomes soft and crumbly like 12; (15) compact felstone concentrically stained with iron veinings.

The general dip of these beds is easterly, but owing to the inequality of the hill, and partly perhaps to irregularities in the dip, their strike forms a wavy line from north-west to south-east. Some of them can easily be traced along nearly the whole length of the hill; thus the ashy layer, lying irregularly in the cliff behind the west wing of the High School, rises westward, forms the bed west of the monument (10 in the section), and then crosses over below the Transit House to the north-western declivity, where it is lost below the débris. Again, the ashy bed 14, with the peculiarly veined felstone (15) which overlies it is also seen near the foot of the pathway ascending from Greenside Church. This felstone (15) should be compared with that already noticed at St. Margaret's station; each forms the highest visible bed in its locality, and they resemble each other very closely. The felstone (11) where displayed below the Transit House, has a fissure containing pieces of anthracite. Two small greenstone dykes traverse the traps of the Calton Hill, one running east and west a little south of Greenside Church, the other (as I was informed by the late Dr. Fleming) crossing the road near a seat to the north-east of the National monument, but only seen when the ground is bared of gravel.

The felstones of Arthur's Seat form the highest of the Carboniferous rocks of the hill, but their top is not visible owing to the depth of sand and clay which lies along the eastern declivity. No rock occurs for a long way, so that the upper boundary line of these traps must be somewhat arbitrarily drawn. We obtain better evidence, however, from the ground to the east of the Calton Hill. The felstones can there be traced eastward into the garden enclosures attached to the houses of Royal Terrace, while a short way beyond we find Carboniferous sandstones and black shales dipping east at 25°. The upper limit of the felstone, therefore, occurs about 80 yards east from the west end of the Terrace. At the east end or apex of the Terraces sandstone was once quarried, and the rents in some of the houses are due to the subsiding of the rubbish cast into the old quarry holes.*

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* I use this term for beds of trappean material, which has been ejected as dust and broken fragments, and become subsequently assorted in water; but in the case of these Calton Hill beds, as in those of the Pentlands already described, it is very difficult to decide which have been produced in this way, and which have resulted from the abrasive force of moving water acting on hardened lava-flows. The term *ash* cannot fairly be applied to the latter, and *trap-tuff* seems equally objectionable.

Craiglockhart Hill.—This eminence lies about 3 miles south-west of Edinburgh, and has been already mentioned as probably contemporaneous with the ashes and basalts of Calton Hill and Arthur's Seat, on the other side of the great anticlinal axis of the Pentlands. Its structure is very simple. The lowest bed or series of beds consists of yellowish green felspathic ash, containing in some places crystals of augite and pebbles of quartz, and occasionally enclosing large angular blocks of sandstone and quartz rock. The upper bed is a dark amygdaloidal columnar greenstone, the whole dipping W. by N. below sandstones and shales, the angle of which is 30°. The north-east end of the hill must be skirted by a fault, since the ash is abruptly truncated there, and replaced by sandstone in the parks about Craig House, the sandstone in an old quarry dipping nearly north at 33°.

CHAPTER V.

LOWER CARBONIFEROUS SERIES BETWEEN THE ARTHUR'S SEAT GROUP AND THE CARBONIFEROUS LIMESTONE.

THE geology of the region west of the Pentland axis is one of the most complicated in central Scotland. The strata, though forming on the whole an ascending series from east to west, present a most irregular and contorted aspect when traced into details. The whole area from the Pentlands to the Bathgate Hills and Linlithgow consists of an almost hoplessly confused assemblage of anticlines and synclines, whereby the carboniferous series is thrown into endless irregular undulations. Moreover, faults abound and huge masses of intrusive trap intersect the district in every direction, while to complete the difficulties drift clay and sand cover deeply most of the lower grounds, and even rise to some height along the eastern flanks of the crags and hills. These features are best exhibited on the map in the space between Queensferry and the Bathgate Hills, the outcrop of the Houston coal and the Queensferry limestone forming traceable lines by which the curvatures of the district can be clearly shown.

The trappean rocks of Arthur's Seat and Calton Hill, as shown in the preceding chapter, are overlaid by a series of sandstone bands with interstratified dark shales. The lower part of this series is visible in places on the east side of Calton Hill, at the back of Royal Terrace. From the enclosed character of the ground, and the depth of drift to the north and east, no adequate sections can be obtained. Hence we cannot satisfactorily dovetail these sandstone and shales with the undoubtedly higher shales of Wardie, though from the evidence at present existing it seems probable that the Wardie beds will be found between the Calton Hill and Lochend, with an easterly dip, and that they consequently graduate downward at no great distance into the Royal Terrace beds. If this supposition be correct, we may connect the sandstones of Lochend, the Black Rocks, and Granton as parts of one series arching round the northern termination of the anticlinal axis of the Pentlands. Some confirmation of these views is obtained by tracing the Wardie shales southwards by the Water of Leith to Slateford, and thence to the fault at Colinton. Above Katesmill they begin to be underlaid by bands of sandstone, shale, and fine conglomerates, very similar to the strata in the sections behind Royal Terrace. The lowest beds visible are the highly inclined plant-bearing sandstones of Colinton, which are thrown down apparently by the long Castle fault against a lower part of the series. South-west of this point, although the undulations are almost without end, and the shales re-appear in the channel of the stream overlaid by a thick sandstone series, I do not think we have the Royal Terrace and Katesmill beds again repeated to the west. Notwithstanding the frequent curvatures, the series, as we proceed west, slowly ascends, until at Baad's Mill, Bathgate, and Linlithgow, we come to the lower beds of the Carboniferous limestone.

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* This fact was communicated to me by the late Mr. Alexander Rose, long known in Edinburgh as a careful and experienced mineralogist.

Wardie Shales.—The shales of Wardie (or Newhaven), a village on the Forth, about 2 miles north-west of Edinburgh, have long been known to the palæontologist as one of the earliest searched localities for icthyolites in Scotland. Agassiz enumerates six species found here, and some of them were generically new to that naturalist.

The following is Agassiz's list:—

Amblypterus nemopterus.
A. punctatus.
A. striatus.
Eurynotus fimbriatus.
Palæoniscus carinatus.
Acanthodes sulcatus.[*]

They occur in oblong flattened nodules of clay ironstone, which also contain coprolites, plants, and septarian veinings of carbonate of lime. There are also shells of the genera *Anthracomya?* and *Anatina*, with *Lingula squamiformis.* The shales are dark grey or black, hard and sandy in some layers, soft and argillaceous in others. Many of the partings when laid open display a confused assemblage of fern-fronds (*Sphenopteris*), grass-like stems, *Lepidostrobi*, and fragments of *Lepidodendron, Calamites,* &c.[†] The undulations of these strata, their faulting, the details of their stratification, and their fossil contents, can be admirably studied along the shore.

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[*] To these must be added *Rhizodus Hibberti.*

[†] At Slateford they contain a beautiful new fern of the genus *Adiantites*, of which only one specimen exists, found by Mr. Richard Gibbs.

The Wardie shales can easily be traced for 6 or 7 miles southward. After leaving the sea they take a persistent westerly dip, and are next seen in the channel of the Water of Leith at Stockbridge, while a lower part of the group occurs in the section at the Edinburgh Station of the Caledonian Railway. They again appear at Slateford, still retaining their westerly inclination, and abounding in plants, coprolites, and fish remains. From this point they continue up the stream which flows nearly along their strike, till at Katesmill, owing to a southward curve of the channel, the lower strata alone are seen. Between Juniper Green and Kenleith they again appear, and pass below a set of yellow and white sandstones, occupying the lower part of Kenleith Burn. Another synclinal curve above Currie brings the shales up once more, but in their south-western course they gradually lose the massive homogeneous character which marks them at Wardie and Slateford. Instead of consisting almost wholly of shales the series by degrees becomes more and more split up by intercalations of sandstone. Hard cherty limestone bands also become more numerous. These changes go on until towards the Cairn Hills shale almost disappears, and the whole of this part of the Lower Carboniferous series passes into a set of variously stratified sandstones.

Limestones in Lower Carboniferous.—The limestones in the middle and lower part of the Lower Carboniferous series appear to be very local in character. They are sufficiently abundant, however, to deserve attention, and fully justified Mr. Maclaren in classing the mass of strata between the Carboniferous Limestone and the Old Red Sandstone as "Calciferous Sandstones." They occur as bands varying from a few inches to several feet in thickness, and have a compact, cherty, sometimes brecciated texture; but, so far as I have observed, without fossils. They may be seen in the section at the Edinburgh Station of the Caledonian Railway, in several places along the course of the Water of Leith, as at Currie and Lymphoy, in Balerno Burn, near the bottom of Cock Burn, where at least five seams may be counted close together, and in other localities.

Granton and Craigleith Sandstones.—Above the Wardie shales comes a vast series of yellow and white thick-bedded sandstones with occasional partings of shale. They are well shown on the shore between Granton and Queensferry, and have been largely quarried at Granton, as well as inland at Craigleith, Redhall, Hailes, and Humbie. Each of these quarries furnishes an ample field wherein the beginner may study the stratification of rock-masses, and a few hours spent attentively there will probably teach him more than he could learn from whole pages of description.

In quarrying these sandstones there are two chief kinds regarded as valuable for architectural purposes. One occurs in thick beds without any, or with only a slight trace of stratification in the body of the stone, which is then called *liver-rock*. It can be removed in blocks of almost any size, is susceptible of a good polish, and is used for the *ashlar-work* and carvings of houses and public buildings. The other kind lies in well-marked beds, often with coaly partings between, and is removed in smaller blocks for *rubble-work*, stone-dykes. &c.

This sandstone series abounds with the remains of plants usually defaced and fragmentary, indicating a protracted maceration before final entombment in the sandy sediment. Occasionally, however, well-preserved specimens occur, as of *Lepidodendron elegans* at Redhall, and *Sphenopteris affinis* at Granton. Large trunks of coniferous trees have also been met with at Granton and Craigleith.*

The Granton and Craigleith sandstones follow the same general course as that of the Wardie shales, but the similarity of all the parts of the series to each other renders it difficult, if not impossible, to map them except in a very general way. We know that they overlie the Wardie Shales, and that in many undulations they occupy the wide area between Granton and Dalmeny southward to the foot of the two Cairn Hills, and thence into Lanarkshire. But towards the south, owing to the thinning away of the Wardie Shales, they seem to pass down insensibly into the thick sandstones of the Cairn Hills, while their upper limit from the drifty nature of the ground can only be approximately reached.

Igneous Rocks contemporaneous with the Granton Sandstones.—This series is traversed in many places by masses of greenstone, such as Mons Hill, Corstorphin Hill, Ratho Hill, and Dalmahoy Crags, but as most of these must be regarded, for the present at least, as intrusive, they will be described in a separate chapter. But besides these there are trappean rocks undoubtedly contemporaneous with the strata among which they occur, showing that the deposition of the middle portion of the Lower Carboniferous series of the Lothians was accompanied by occasional volcanic eruptions; of these the first trace, after the quiescence of the Arthur's Seat area, occurs among the sandstones on the shore west of Granton, near Broomfield House, in the form of a pale sandy felspathic ash with white felspathic and irregular fragments of hardened shale. It was quarried behind Laurieston Cottage, but the openings are now filled up. Another and much more important trappean mass belonging to a later part of the same series forms the long ridge called Corston Hill, 3 miles south-west of Kirknewton. It consists chiefly of a dark coloured compact felstone, almost approaching a basalt in places, disposed in the form of an irregular bed, which dips southwards. Where traversed by the Caledonian Railway several ashy interstratifications occur containing numerous fragments of different porphyritic felstones, some of which very closely resemble certain of the porphyries of the Pentlands. It deserves to be remarked that this great trappean bed (for it reaches a length of fully 3 miles, and a breadth of 1 at the thickest part) is the only Carboniferous felstone in this area later than the Arthur's Seat series. With this single exception all the lava-form traps above that series belong to the augitic family, but they do not appear to have commenced until after the ejection of Corston Hill. The order of appearance in Mid Lothian and West Lothian is, therefore, as follows:—Felstones in great variety and to an enormous extent during the Old Red Sandstone; greenstones and basalts, and then felstones to a limited amount, at Arthur's Seat and neighbourhood during the older part of the Lower Carboniferous series; felstone again at one locality during the middle portion of that series, and after that all greenstone and basalt vigorously in Linlithgowshire throughout the rest of the Carboniferous period, as far at least as the close of the carboniferous limestone.

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* These were noticed many years ago, and an account of their internal structure published by Mr. Witham. *See* Foss. Veg., p. 23 et seq. Plates iv. v. vi. and vii., 1835.

When the Granton and Craigleith Sandstone series was drawing to a close, and possibly during the ejection of the lava of Corston Hill, the igneous forces began to show themselves over the area of Linlithgowshire, where eventually they played an important part. The first eruption, at least the earliest of which I have obtained any trace, is a green, fine-grained, felspathic ash. It can be seen in at least two places where the undulations, so frequent throughout the eastern part of this country, have brought it to the surface. Of these one is the rounded eminence called Tor Hill behind the village of Ecclesmachan; the other lies at the south end of Binny Craig. Reference to the map will show that the ash of Tor Hill forms the end of an anticlinal axis, from which dip away on every side but the north, shales of the Queensferry (Burdie House) Limestone Group. The rock is a dull, yellowish or greenish-grey, brecciated, felspathic ash, consisting of green, angular, felspathic fragments, which contain rounded grains of quartz, and are imbedded along with rounded pebbles of cherty limestone in a dull grey felspatho-calcareous paste. The quarry on the east side of the hill shows angular fragments of yellow baked shale, and balls of different traps. The Binny Craig ash lies about a mile and a half to the south-west of Tor Hill, of the rock of which it is probably a prolongation. Ten miles southwards, near Harburn Tile Works, another ashbed occurs, along with two thin seams of coal; but the structure of that district is very obscure, and I have not been able to determine whether these strata may not belong to the horizon of the Houston Coal (to be immediately described), a part of the Lower Carboniferous series considerably higher than that of the ash at Tor Hill. Whilst mapping the mossy country between West Calder and the Cairn Hills southwards into the borders of Lanarkshire, the Lower Carboniferous series as a whole, I conjectured, must be thinning towards the south-west; but the data obtainable were too few to warrant any positive conclusion. Subsequent investigations in Lanarkshire, however, have confirmed the inference then drawn, for in a space of about 15 miles the whole of the enormous Lower Carboniferous series of the Lothians dies off, and the Carboniferous

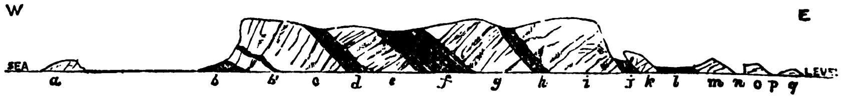
Limestone comes to rest directly and unconformably upon the Lower Old Red Sandstone.*

Lower Carboniferous Rocks of Forth Islands and part of Fife Coast.—Before noticing the next stratum of importance in ascending order, the Burdie House or Queensferry limestone, it is necessary to glance at the development along part of the Fife coast and in one or two of the islands in the Firth, of the strata now described. The details of that coast line, of which so small a portion is embraced in the present sheet, are so intimately connected with a proper understanding of the geology of the interior of the country that they will be more appropriately discussed in the Memoir to accompany Sheet 40. The strata underlying the Burntisland (Burdie House or Queensferry) limestone are sandstones and shales equivalent to those already described on the shore at Queensferry. They are seen between Aberdour and Burntisland with ash beds and involved greenstones.

The island of Inchkeith affords an admirable series of sections of the cypris-bearing shales and limestones immediately below (if not on the horizon of) the Burdie House limestone. They are intercalated among greenstones and ashy beds, and this union of harder and softer rocks has given rise to the singularly diversified contour of the island, the greenstones running out as long reefs and ledges while the sedimentary rocks have been worn into narrow inlets and sandy bays. The bedded character of the island, traps alternating with sandstones and shales, is sufficiently indicated on the map, though of course on such a small scale, only the more important beds can be shown. The subjoined section, however, taken at right angles to the dip through the north end will better illustrate its detailed structure. The lowest greenstone (*a*) forms part of a set of low skerries on the west side of the island, covered at high-water mark—the evident fragments of other greenstone beds to the west. The intercalation (*b*) consists of rippled carbonaceous sandstones and shales dipping below the greenstone of the cliff at 40°. The greenstone (*c*) is soft earthy strongly amygdaloidal, and southwards, on the face of the " Cawcans " cliff, well columned. Towards its base it has involved some masses of sandstone and shale (b^1), and one bed not so contorted as those below contains *Cyprides* in abundance. This greenstone is covered by (*d*) beds of white

Fig. 7.

SKETCH-SECTION OF INCHKEITH (NORTH END).



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* *See* Quart. Journ. Geol. Soc., vol. xvi. p. 319.

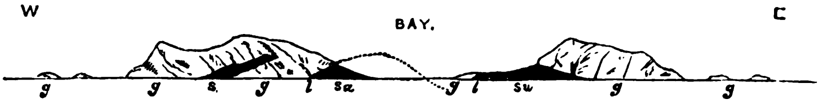
grey and greenish cherty and brecciated limestone, with intervening seams of red and greenish friable marly shales. A soft green, strongly amygdaloidal greenstone (*e*) supervenes, covered by a comparatively thick series of sedimentary beds (*f*) highly inclined. They consist of limestones, shales, and sandstones, like those below, but include also a thin lenticular bed of green fine-grained felspathic ash, seen on the shore between high and low water mark. The greenstone (*g*) which covers them shows at the bay called Kinghorn Harbour, another lenticular bed of ashy conglomerate and a little higher up some seams of shale with *Spirorbis carbonarius*, but these thin out rapidly to south. Grey micaceous sandstones with some shale (*h*) next occur. They can be traced southward along the west front of the island, where they contain some limestone bands, but their termination becomes involved and entangled among greenstone. The next greenstone (*i*) forms the most northerly point of Inchkeith and runs out to sea as the sharp promontory called the East Stell. Thence it swells out southward forming the main ridge of the island and continuing to the southern point called the Long Craig. The green marly shales and nodular limestones (*j*), owing to the thinning away of the greenstone (*k*) to the south, unite with similar beds (*l*), and extend along the whole of the eastern shore. Further south than the point which the section crosses they contain a seam of felspathic ash and a layer of coal 3 or 4 inches thick. The next greenstone bed (*m*) has been much abraded by the sea, and forms a line of singularly picturesque skerries. Its upper surface about the middle of the coast-line has a rough shaggy, scoriaceous appearance, balls and fragments of amygdaloidal greenstone being there wrapped in a green concentric paste. The thin shaly partings (*n*) and (*p*) are almost wholly concealed by the débris and by the waves. Where I saw the first (*n*) they consisted of a flinty limestone and some black shales, the whole being only 3 or 4 feet thick. The other interstratification (*p*) was wholly shale. The greenstone (*o*) resembles that last described, but is occasionally columnar. The last greenstone of the series (*q*) I merely saw, as the waves of the turned tide were dashing over it.

That some at least of these trap-rocks are contemporaneous with their associated strata I have little doubt, the ashy layers sufficiently proving the existence of volcanic ejections at the time. The greenstone (*m*) at once recalls the slaggy character of the upper surface of a lava-flow. It is true that some of the traps unite (*c* and *e* for example), and the sedimentary partings disappear; but the strata are nowhere much altered, save when actually involved in the trap (as in *c*).

I may include here a notice of the other islands of the Forth. Inch Colm consists of intrusive greenstone among sandstones, shales, and thin limestones. These strata are probably not far from the horizon of those on Inchkeith. The structure of the island will be best understood from the accompanying sketch-section (fig. 8). It is taken along the length of the island and

Fig. 8.

SKETCH-SECTION OF INCH COLM.



across the bay on the south side of the abbey. The greenstone (*g*) of the south-west limb of the island incloses a band of shales and shaly limestones (*s*) all considerably hardened. This part of the island has a westerly dip, so that the flinty limestone and shales (*l*) and the hardened sandstones (*s a*) on the west side of the south bay are repeated on the east side where the dip changes to an easterly direction. There are some interesting anticlinal foldings of the same strata on the shore, which will be described in the Memoir of Fife.

Another island called the Carcraig, about half a mile to the north-east of Inch Colm, consists of greenstone dipping east by north at 20°, and resting on sandy shales and limestones containing *Myalina*. A thin bed of greenstone lies intercalated among these strata.

The other islands marked on the present Sheet all consist solely of greenstone or basalt, and do not call for any special remark. Before returning to the strata on the south side of the Firth, I may state here again that the Fife coast is reserved for description in a separate Memoir, and will only be incidentally referred to in the following pages.

Burdie House or Queensferry Limestone.—After passing upward through the great sandstone series of Granton and Dalmeny, we come to a well marked zone of limestone and shale. It was first studied at Burdie House, about four miles south of Edinburgh, where the limestone yielded to the late Dr. Hibbert the remains of a remarkable series of ganoid fishes. His interesting memoir* soon brought the locality into notice, and the Burdie House Limestone has since found a place in almost every elementary manual. Although the set of strata now to be described is called a limestone group, it must not be supposed that, as in the case of the carboniferous limestones above, there are any bands of limestone persistent over wide areas. On the contrary, nothing can be more variable than the thickness and lithological character of this group. In some places it contains one single bed of limestone 40 to 70 feet thick, while at no great distance this mass entirely disappears, and is represented by thin calcareous shales. I shall first describe this series as it appears at Burdie House, where it was originally studied and then trace its course throughout the district to the west of the Pentland Hills.

The limestone of Burdie House attains a thickness of 27 feet. It has a dull yellowish or blueish grey colour, and, in certain strata, a finely striped appearance, owing to the greater or less amount of carbonaceous matter in the layers. It is compact, sparingly crystalline in some bands, and occasionally contains thin laminæ of coaly matter, which impart a fissile structure. The following organic remains have been found here :—[*]

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* Trans. Roy. Soc. Edinb., vol. xiii.

Fossils of Burdie House Limestone.

Sphenopteris affinis.
S. bifida.
S. crassa.
Lepidodendron Sternbergii.
Lepidophyllum intermedium.
Lepidostrobus comosus.
L. ornatus.
L. variabilis.
Cyperites bicarinata.
Calamites.
Sigillaria.
Stigmaria.
Cardiocarpon acutum.
Cypris Scoto-Burdigalensis, Hib.
Cypridina [*Daphnoidia*] *Hibberti.*
Anthracosia [*Unio*] *nuciformis.*

Ctenodus Robertsoni.
Ctenoptychius denticulatus.
C. pectinatus.
Gyracanthus formosus.
Ptychacanthus sublævis.
Sphenacanthus serrulatus.
Cladodus Hibberti.
C. parvus.
Diplodus minutus.
Rhizodus [*Holoptychius*] *Hibberti.*
Uronemus lobatus.
Megalichthys Hibberti.
Palæoniscus ornatissimus.
P. Robisoni.
P. striolatus.
Eurynotus crenatus.
Pygopteris Bucklandi.
P. Jamesoni.

Some of the shales above the limestone are worthy of note from the abundance of their fossil contents. One thin band of shale in particular consists mainly of cypris-cases, which impart to it a fissile structure.

South of Burdie House the limestone ceases to be traceable, owing to the depth of the covering of drift. In several of the streams which descend from the Pentland Hills, however, blocks of it can be seen, indicating its probable continuity southwards; and at Carlops, 10 miles south of Burdie House, it is found among the vertical strata in the river Esk, but as two beds, 4 and 5 feet thick respectively. Its prolongation north of Burdie House is wholly uncertain; probably it is cut out by the great fault which, running by Liberton to Portobello, brings down the Mountain Limestone and overlying Coal-measure almost vertically against the bottom beds of the Carboniferous group. The thickness of the rock at Burdie House is probably exceptional, the rock there seeming to have been formed in a hollow or lagoon, which shallowed southwards—a supposition rendered probable from the appearances presented by the rocks of Linlithgowshire.

In that county there occurs, sometimes fully 1,000 feet below the mountain limestone, a seam of grey compact stratified limestone, averaging about 9 feet thick. In colour, texture, and fossils it corresponds closely with the rock of Burdie House, of which, indeed, there can be no doubt that it is the equivalent.

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[*] Hibbert, loc. cit.

Along the shore, between Queensferry and Midhope Glen, the beds undergo frequent reversals of dip, and the limestone, with its associated shales and sandstone, can be seen crossing the beach five times. There it has the usual texture, but as we trace it inland it gradually becomes more argillaceous, splits up into thin layers, and passes finally into calcareous shales, with little resemblance to the limestone, except that they contain the same fossils. Still further to the south the rock regains its purity, and has been extensively worked at Dechmont, but to the south-east of that district it again becomes shaly and argillaceous, till it takes the form of fissile grey shales, whose identity with the limestone of Burdie House could hardly at first sight be suspected. Beyond this it re-assumes its typical character, and at Midcalder and Murieston occurs in great basin-shaped cavities 40 to 70 feet deep. At the Midcalder quarries it exactly resembles some parts of the rock at Burdie House, being full of plants, especially of *Stigmaria*, which spread out their long roots in regular layers, with the rootlets branching freely in all directions, as if, when the limestone existed as soft calcareous mud, the plants grew upon the spot where we now find their remains. From these different facts it appears that the Burdie House limestone was formed very slowly, probably in brackish water, across a series of lagoon-like depressions, separated from each other by muddy shoals; that in these hollows cyprides and ganoidal fishes abounded, while even the larger placoids became occasional visitors; and that in some localities there rose up from the muddy bottom a thick growth of marshy plants.*

Strata between the Burdie House group and the Carboniferous Limestone.—At Burdie House there supervenes a thickness of about 800 feet of sandstone and shale between the limestone now described and that of Gilmerton, which latter belongs to the Carboniferous Limestone series. Along the east side of the Pentlands neither this, nor indeed any portion of the Lower Carboniferous rocks, can be traced out satisfactorily. The great fault, as we have seen, throws them on end, and the country is, moreover, deeply covered with the drift-sand and clay which gathered under the lee of the hills. The sections, therefore, where the beds above the Burdie House limestone can be seen are few and wide apart. Nor, indeed, do they present features of much interest; shales and sandstone are visible in the stream above Stenhouse, again on the road, and in the quarries between Straiton and Loanhead, and in Driden Vale, whence, for a long way southwards, deep drift obscures the country, but at Nine-mile Burn, and still better on the Esk, below Carlops, sections are again obtained of the same sandstones and shales.

The development of the same series on the west side of the Pentlands, though more complicated by anticlinal and synclinal flexures, can be much more satisfactorily worked out. An additional feature of interest likewise occurs in that area in the increasing number and variety of the igneous masses. From this point in the ascending series, while volcanic action during the Carboniferous period ceased wholly in Edinburghshire, it went on gaining in intensity in Linlithgowshire.

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* The above outline of the Burdie House limestone group is the same as that which I prepared for the "Descriptive Catalogue of Rock Specimens," in the Jermyn Street Museum. Duplicate specimens were collected for Edinburgh, where they now lie in boxes until space is afforded for their exhibition.

If a distinguishing name were to be given to the series of strata which in the latter county intervenes between the limestone of Queensferry and the Carboniferous Limestone of the Bathgate Hills, that of the "Binny Sandstone Group" might be adopted. We are presented with two great zones of sandstone: an under one, extensively quarried at Binny, and an upper one at Kingscavel, east of Linlithgow. Between these two zones there lies a debateable band of sandy shales and shaly sandstone, where the characteristic stratum is a seam of coal known as the "Houston coal." Throughout this series ash and greenstone everywhere show themselves, while the whole undulates again and again, throwing the beds into almost endless basins and saddle-backs. In no part of the district can the lower part of this series be so well observed as along the Queensferry shore, westwards to Midhope Glen. The frequent changes of dip there visible bring up the beds several times in succession, and enable us to mark how rapid are sometimes the changes which a stratum may undergo in its lithological character over even a very limited area.

The lower zone of sandstones, of which these Queensferry beds form the under portion, resting directly on the limestone and its shales, cannot be seen to greater advantage than in the great quarries of Binny near the village of Ecclesmachan. The finer kind of sandstone or "liver-rock" forms a building stone of the finest quality, and can be quarried in large amorphous blocks. Some of the public buildings in Edinburgh, such as the Scott Monument, are built of this stone. In the north-west quarry petroleum is found in irregular flakes and lumps, coating the surfaces of the joints. Some further facts relative to the occurrence of that substance in rocks of this district will be given in the section upon Intrusive Igneous Rocks. The range of the Binny sandstone will be best followed by marking the outcrop of the Houston coal, by which it is overlaid.

The Houston coal and its associated strata are well shown in the deep cuttings of the Edinburgh and Glasgow Railway at Craigton. The subjoined table represents the section there visible.

DETAILED SECTION of the HOUSTON COAL and its associated Strata, in the Cutting of the Edinburgh and Glasgow Railway at Craigton.

	FT.	IN.
Soft shale, with balls and bands of impure limestone.		
Hard blue calcareous shale - - - - -	3	0
Hard blue shale, with numerous lenticular seams of iron pyrites - - - - - -	12	0

	FT.	IN.
Coal (here altered by a mass of greenstone into a kind of anthracite)	0	2½–4
Shale	0	2–6
Pyritous clay-ironstone, shaly below	0	3–6
Black shale	1	8
Pyritous clay-ironstone	0	4–7
Hard black shale, sandy and pyritous	1	8
Pyritous ironstone	0	3–4
Hard dark blue calcareous shale	0	4–5
"Cement stone," a very hard compact calcareous ironstone	0	6
"Houston coal" 1 foot to	1	6
Black shale	0	6–8
Hard ferruginous sandy parting	0	2½–3
Black shale	1	0
Hardy sandy "cement stone"	0	4–5
Shale parting	0	0–½
Hard blue "cement stone"	0	4
Coal	0	4–6
Hard black shale	0	6
Soft black shale	0	6–10
Altered coal	0	4
Hard shale	1	0
Blue shale, with nodules of clay ironstone - 3 feet to	5	0
Shaly carbonaceous sandstone, passing down into the Binny sandstones.		

In the pit on the south side of the railway two seams of coal were found: a "smithy" or caking coal, 10 or 11 inches thick, and a "household" coal from 2 to 3 feet, the two seams being separated by from 4 to 5 feet of dull shale, with a band of coarse limestone, which passes into clay ironstone. In the workings at Hillend, two miles south of Craigton, the upper seam reaches a thickness of 2 feet 4 inches, the under one 12 to 15 inches, there being here also an intervening band of shale 15 inches to 3 feet thick, with the same intercalated parting of ironstone or limestone. Where the shale is thinnest the coal becomes thickest, and *vice versâ.* In the pits around West Binny, the coal is said to have been six feet thick. Southwards, on the banks of the Breich Water, the "Houston coal" can be seen, and also another seam, which occurs a considerable way above it. With this exception, the coal appears to be confined to one well-defined horizon throughout Linlithgowshire.

The crop of the Houston coal can be traced with considerable accuracy over a large part of the eastern half of this county, but the depth of drift and the want of natural sections make some portions of its course uncertain. Where not itself visible, its position is nevertheless frequently shown by the outcrop of certain green and red marly shales, which occur a little higher in the series. It begins at the coast, near the mouth of Midhope Burn (where, however, its crop is not visible); thence, following the line of the stream, it passes through the grounds of Philpston, having been found in a well near the house. It probably runs westward to beyond Park, where it was cut through in making the bridge and canal. The fault which has severed the ash-bed of Pilgrim's Hill must likewise throw the coal back into the grounds of Champfleurie, where it is said to have been found in boring. From Champfleurie it stretches southwards to Ochiltree, where at one time it was mined to a considerable extent. The records of these workings appear to have been lost. The sinuous crop round the greenstone eminence of Peace Knowe, is succeeded by a straighter line, running west of south by West Binny, where the line of old crop pits can be distinctly traced across the fields. At Drumcrosshall, on the same southerly outcrop, it was once worked, and in some bores put down a few years ago on the south-west part of the property, the coal was found to have a thickness of 6 feet. From this point its course becomes obscured by the drift and peat which cover the great valley east of Bathgate, but we again find it at Seafield, the marls which cover the coal on the Almond south of Blackburn House, and the seam itself on the Breich Water above Westwood. It runs southwards to Blackbrae, but after this it ceases to be visible throughout the peaty ground round Cobinshaw Reservoir, unless the thin seams, previously referred to, at Harburn Tile Works be representative of the Houston coal.

The line of outcrop just described is that of the coal where it dips finally westward below the sandstones that underlie the Carboniferous Limestone; but east of this line the anticlinal folds of the strata have brought down the coal again and again in detached and often very irregular basins. Of these the most northerly, as shown on the map, is that which runs from near Duddingston south-westward to Little Ochiltree, and thence south by east between Binny Craig and the village of Ecclesmachan. Another but much smaller basin occurs at Hillend, about a mile north-east of that village, and the coal is there worked at present. Beyond this, a few hundred yards to the north-east, the seam is thrown in again, one side of the basin having been worked from the canal at Winchburgh to near Lampinsdub, while the other side, owing to the fault which traverses the basin, has never been found. South of the Hillend workings another basin has been worked, the line of pits being still discernible, while still further south, between the two greenstone ridges of Pyothall and Newbigging, the coal has been mined to some extent. The anticlinal axis of Dechmont, by bringing up the Queensferry limestone on either side, has produced another basin of the Houston coal, though, owing to the obscured nature of the surface and the paucity of sections, the line of outcrop cannot be continuously followed. It is well known at Houston, whence it stretches southwards to Livingston with an easterly dip; it is said to have been worked also in the farm of City, but along the east side of this basin I have not been able to find any trace of it. The subjoined section shows the geological structure of this district.

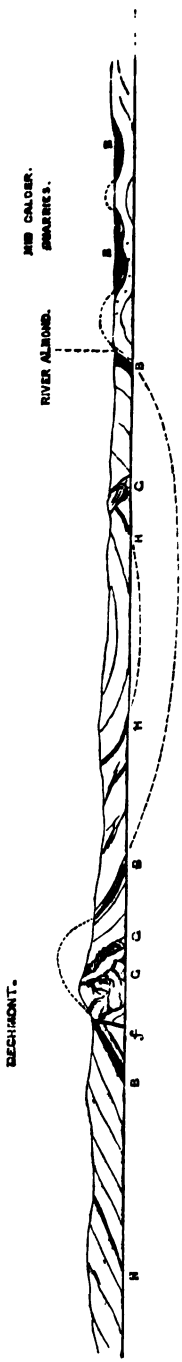

Fig 9.

SKETCH-SECTION FROM NEAR DECHMONT LAW TO EAST CALDER.

H, Houston coal. G, Greenstone. B, Burdie House limestone. *f*, a fault.

The peculiar red and green marly shales which occur a short way above the Houston coal are well exhibited in the railway cuttings at Craigton, also in the Mains Burn, about a mile west of Binny Craig, in the Ecclesmachan Burn below Oatridge, in the river Almond south of Blackburn House, in the Breich Water at Breich dyke, and in other localities. Above these shales lies a great series of white sandstones, similar in general character to those which underlie the coal. Along with some minor alternations of dark shale containing plants they occupy the remainder of the Lower Carboniferous series up to the base of the marine limestone. They are best seen in the large quarries at Kingscavel, east of the town of Linlithgow, but may be traced across the county from the sea at Blackness to the Breich Water. Their chief feature of interest is the great number and variety of their interbedded igneous rocks. Before passing on, therefore, to notice the Carboniferous Limestone, I shall briefly enumerate the more important masses of contemporaneous trap between that limestone and the limestone of Queensferry.

Contemporaneous Igneous Rocks between the Granton Sandstone Series and the Carboniferous Limestone.—Reference has already been made to one or two exposures of a fine-grained felspathic ash below the Queensferry limestone, indicating the commencement of a trappean series. After the deposition of that calcareous seam similar ejections of volcanic material took place, and gradually on a more extended scale. Of this we have abundant evidence in the sandstone series above described as overlying the limestone. Beginning on the shore west of Queensferry, in the centre of one of the synclinal troughs we find the denuded remains of a sheet of the usual fine-grained greenish felspathic ash. Passing southwards to Niddry Castle a similar rock, also above the limestone, is admirably displayed in the cuttings of the Edinburgh and Glasgow Railway. It occurs likewise on the river Almond below Newliston, six miles westward in the wood south of West Binny, and about two miles south of the latter locality, close to Dechmont House. The character of this ash varies considerably at each of these localities, and though in a general way the rock occupies the same horizon in all, yet it may not improbably be the product of different eruptions. At Niddry it is of a dull green or grey colour, made up of small lapilli in a dull granular or compact felspathic paste. These lapilli are chiefly felspathic, angular, and sub-angular, of a light grey or green colour, and contain minute crystals of carbonate of lime, quartz granules, and angular specks of black shale and occasional grains of carbonate of copper seen on a weathered surface. Large masses of shale and ironstone occur in the ash, sometimes in alternate layers, as if deposited in hollows of the ash, but frequently imbedded vertically. One mass of the former kind on the south side of the railway cutting measures 36 feet long, and consists of a number of alternating strata of shale and ironstone, its ends being completely truncated by the ash,* while large rounded and irregular masses of calcareous ironstone lie scattered in the ash, chiefly on the east side. A block of black shale stuck vertically in the ash measures 10 feet high by 6 feet broad. In no part of Linlithgowshire does any ashy deposit present the tumultuous unstratified aspect and enormous imbedded masses seen in this Niddry rock. It has no visible stratification, and weathers into a rude spheroidal structure like a greenstone. In different parts knobs and veins of greenstone occur intruded irregularly into its mass. The rock at the Queensferry shore is a much finer-grained ash, with small rounded grains of quartz; that at West Binny approaches nearer to the aspect of the Niddry deposit, its sub-angular lapilli are white, with the usual siliceous granules, in a dull greenish brown felspathic matrix.

The area over which this horizon of ash can now be traced is a triangular space, of which the two sides extend for about six miles, and the base for nearly four. Above these ash beds, and immediately below the Houston coal, a bed of greenstone, probably contemporaneous, occurs at Peace Knowe, Wester Ochiltree. It forms an irregular anticlinal axis, round which the coal winds, as shown by the line of old crop pits whereby the seam was formerly worked.

Above the Houston coal another series of ash beds occurs, and likewise great sheets of contemporaneous greenstone and basalt. Indeed, as stated at the close of the previous section, the sandstones between that coal and the Carboniferous Limestone are mainly characterised by the abundance and wide extent of their igneous rocks. Near the base of these sandstones, and but a short way above the coal, a green felspathic ash (B′ in fig. 10) occurs on the lands of Binns, at the south lodge. It occupies but a limited extent, and is quite distinct from the rock of Binns Hill.

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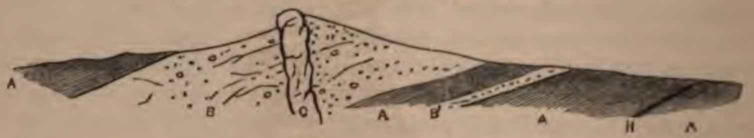
* I am strongly inclined to view this mass as having been torn up and re-deposited in its present position. I could find no evidence of any pause in the ejection of volcanic material, such as would have been necessary to the accumulation of these strata in the hollow of the ash.

Binns Hill is the largest mass of ashy material in the county, and the only one which appears still to exhibit the vent from which that material was ejected.

It acquires, moreover, additional interest from the fact that on the same general horizon a mass of similar ash runs southwards for six or seven miles, while another large patch occurs seven miles to the north-east on the coast of Fife. The structure of Binns Hill is shown in the subjoined section. The ash (B) has the usual greenish tint, and contains rounded and subangular fragments of shale and ironstone. As shown in the section, the top of the hill is occupied by a circular patch of basalt (C), black and very compact. It has exactly the form of a volcanic neck, and if the ash were cleared away round its edges the basalt would, I have no doubt, been found descending as a long column. Denudation has partly effected this on the west side, where, consequently, the basalt can be traced 70 feet lower than on the east side. A similar example of a *plug* of basalt filling up a crater will be pointed out in describing the newer igneous rocks of Arthur's Seat. The reader, however, will guard against the impression that the existing summit of Binns Hill represents the original mouth of the vent; much of the surrounding ash has been denuded away, along, perhaps, with part of the upper portion of the column, while, although the basalt occupies the vent-hole, it may never have risen to the surface. We see in truth merely the isolated fragments of a former volcanic area, and we need in imagination to piece these fragments together, and supply besides a vast extent of vanished material, ere we can form any adequate conception of the physical aspect of Linlithgowshire, when Binns Hill existed as an active volcano, and scattered ashes and dust over a district of probably more than a hundred square miles.*

Fig 10.

SKETCH-SECTION OF BINNS HILL.



A, Carboniferous sandstones and shales.
H, Houston coal.
B, B′, Felspathic ash.
C, Basalt of crater.

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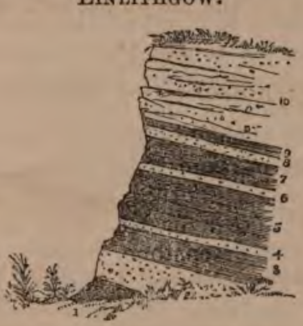
* As these ash-beds can of course be traced solely along their line of strike, we can only measure in one direction the area over which the ash fell, and even that in an approximate way, owing to the drifty nature of the country. If, however, we mass as one all the ash-beds which occur on the same general horizon, we shall find them range from St. David's in Fife to Drumcross, 6 miles due south of Linlithgow, a distance of 13 miles, with Binns Hill in the centre; and if we allow an equal range east and west, the total area covered by these eruptions would be roughly 170 square miles.

The other beds of ash, which I regard as probably southward prolongations of Binns Hill, are seen at intervals from Riccarton to Drumcross, with a westerly dip, while one detached outlier occurs to the east of this line in the centre of a basin of the Houston coal, between Threemiletown and Little Ochiltree. There are many good sections along the banks of the streams, particularly between Drumcross and Bankhead. An instructive section occurs in an old quarry on the side of the stream west of Wester Ochiltree. The lowest bed is a fissile black shale (1), covered by a concretionary ash (2) of a bluish grey hue, with felspar crystals and fragments of black shale. Above this lies another stratum of black shale (3), overlaid by a thin band of pale yellowish fine-grained ash (4). Another bed of similar shale (5) occurs containing rounded balls of ash, and passing up into another ashy layer (6). The shale (7) which succeeds contains thin seams and balls of clay ironstone. It is overlaid by an ash (8) similar to those below, and then by another black shale (9), in which occur well-marked coprolites of *Rhizodus* (?) and abundance of *Cyprides*. This last stratum shades upward into a green ashy conglomerate (10), which consists of a coarse gravelly paste, with rounded balls of greenstone varying from less than an inch to nearly a foot in diameter.

Fig. 11.

SECTION IN OLD QUARRY, WEST OF WESTER OCHILTREE, LINLITHGOW.



Above the ash just described there occurs at the Longmuir Plantation a great sheet of greenstone, the base of which is exposed along the banks of the stream to the east. Where the upper surface of a greenstone bed is concealed, as in the present instance, it becomes by no means easy to decide whether the bed should be regarded as *intrusive*, that is, later than the rocks among which it occurs, or *interbedded*, that is contemporaneous with them. If the bed is quite regular in its course, and occurs in a district where ash beds abound, we shall probably not err in regarding it as interbedded or contemporaneous. Such is the case with the Longmuir greenstone. It lies at the base of a great series of greenstones and ashes, and is underlaid, as we have seen by another important set of ashes, and when viewed in connexion with some of the higher traps of the series, it will be seen to belong with most probability to the contemporaneous series.

The Longmuir greenstone is overlaid by various sandstones and shales, which are seen in the quarry above Broomyknowes (where a thin seam of coal also occurs), and at intervals along the eastern slopes of the Riccarton Hills. They have a westerly dip, and pass below an enormous sheet of greenstone, forming the greater part of the hills, and extending southwards into the Bathgate bogs a distance of nearly five miles. The thickness of this mass along the Riccarton Hills must be fully 400 feet, and it probably reaches double that amount as it approaches Caputhall. I speak of it as one mass, because, in mapping, it cannot be subdived, but in reality it is not all the product of one eruption, as is clear both from the bands of varying texture which it presents and from the occurrence of intercalated seams of sandstone and ash. For instance, in the middle of the mass, half way between the summit of the hill and the road at Beecraigs, a thin interbedded stratum of sandstone occurs, thinning away apparently both to north and south. The rock below this sandstone is hard and compact, like a basalt, while above it has the usual texture and aspect of a greenstone. Again, in a wooded hollow, east of the Kirkton Lime Works, a band of felspathic ash occurs in this trap, and the rock on either side presents a similar difference. The greenstone is in some places markedly amygdaloidal, its cavities being for the most part lined with carbonate of lime,—a structure which is seen in the stream below Broomy knowes farm-steading. As a rule, however, it is granular and compact, formed of a mixture of felspar and angite, and weathering with a crumbling spheroidal surface. The joints which traverse it have their surfaces sometimes slickensided and coated with a film of serpentine or with carbonate of lime, as in the quarry 300 yards north-west of Boghall, east of Bathgate. A remarkable feature occurs in the quarry half a mile east of Boghall; the compact greenstone there, when broken, emits a strong bituminous odour, and when I visited the quarry there were on some of the joints drops of brownish water, which, when evaporated on the skin, gave off the same marked odour, but without any perceptible taste. The same peculiarity distinguishes nearly all the intrusive greenstone of this part of the county (*see* Chap. xi.).*

The Riccarton greenstone is covered by sandstones, some of which are seen in an old quarry on the road side between Beecraigs and Whitebaulks; they are probably on the same horizon as those of Kingscavil. Above them comes the lowest bed of limestone in the Carboniferous Limestone series which may be traced from Carsie Hill, east of Cauldhame, to Whitebaulks, thence, inferentially, between the greenstones to Tartraven, and again at Kirkton; but the southward prolongation of this limestone and the beds which underlie it becomes commingled with the trappean masses of the district, ash-beds, greenstones, and basalts take the place of sandstones and shales, and this feature continues through the whole of this series, as developed near Bathgate. Hence the ash-beds which overlie the Riccarton greenstones to the south will be more appropriately described in the next chapter along with the limestones. Having now ascended through the whole series of the Lower Carboniferous rocks, with its associated contemporaneous igneous masses, we pass upwards into the Carboniferous Limestone group.

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* *See* also Descriptive Catalogue of Rock Specimens in the Museum, Jermyn Street, Second Edition, p. 357.

CHAPTER VI.

CARBONIFEROUS LIMESTONE OF LINLITHGOWSHIRE.

LOWER LIMESTONES AND TRAP-RIDGE OF BATHGATE HILLS.

As the development of this series in Linlithgowshire differs in many respects from that of the same series in the county of Edinburgh, the two districts will be best described separately. The Edinburgh coal-field, therefore, with its encircling zones of limestone, forms a separate part of this Memoir, and is described by Mr. Howell (Chap. viii.) I shall here continue the Linlithgowshire section upward from the Riccarton traps without referring to the contemporaneous strata eastward, and the reader will bear in mind that during the accumulation of the markedly volcanic series of Linlithgowshire now to be detailed, the area of Edinburghshire remained unvaried by the ingress of any igneous rock.

Unfortunately the present Sheet No. 32 embraces only a part, and that the least typical part, of the Carboniferous Limestone series of Linlithgowshire. As the description of the included portion would by itself be much too incomplete and obscure, and as the Bathgate Hills, moreover, form a well-defined independent area, I have included the whole in the present Memoir, and refer the reader to Sheet 31 (not yet published) for the general disposition of the rocks.

The great limestone beds, so admirably displayed on the Fife coast at Charleston, are not visible on the opposite shores of the Firth. There occurs indeed a band of coarse sandy limestone at Blackness, and a still thinner encrinal seam in the quarry on the shore at Carriden, the one marking probably the lowest limit, as the other undoubtedly forms the highest of the lower series of limestones; but of the great encrinal limestone there is no trace on the shore, save in the numerous scattered blocks on the beach below Stacks. The missing beds, therefore, must be supplied from the interior. Passing westwards, we find the Carriden limestone band surmounted by a great group of coal-bearing sandstones and shales with thick interbedded sheets of greenstone forming the coal-field of Borrowstowness. West of Kinneil, two upper strata of marine limestone occur above the coals with the same fossils as in the lower limestones, thus binding the whole into one great palæontological group, the equivalent of part at least of the Mountain Limestone of England.

The Carboniferous Limestone series of Linlithgowshire therefore may be regarded as broadly characterized, like that of the rest of central Scotland, by three well-marked zones :—1st, and lowest, a set of marine limestones with sandstones, shales, and one or two seams of coal; 2nd, a considerable thickness of coal-bearing beds, forming the Borrowstowness coal-field, and equivalent to the Edge coals of Midlothian; 3rd, a group of sandstones with two or three thin but markedly persistent bands of marine limestone. Above these come the upper coals, which probably represent the lower part of the true Coal-measures of England.

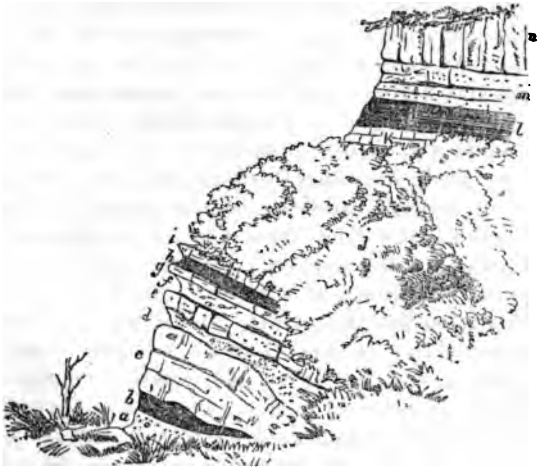
The lowest of these zones rests upon the sandstones covering the Riccarton greenstone, and is consequently the next group to be described. As just remarked, no part of it appears on the coast except the highest and lowest bands, nor until we pass inland for 3 miles does it unequivocably appear; but from Hillhouse, south of Linlithgow, across the hills to Bathgate Muir, it has been admirably displayed in a long range of quarries. The lowest limestone of the series is that formerly worked at Whitebaulks and Tartraven; it is about 10 or 12 feet thick, of a compact blueish grey texture, with abundant fragments of small encrinites, and rests on an 8 or 10 inch seam of coal. At Whitebaulks the strata underlying this limestone are the sandstones above noticed, but as we pass southwards the space between it and the great Riccarton greenstone becomes occupied chiefly by igneous rocks. The sandstones die out, and resting directly on the greenstone we find at Craigs a characteristic ash, and at Kirkton an assemblage of ash, shaly limestones, and basalts. The Tartraven limestone cannot with certainty be traced south of that locality. The country there consists of long east and west ridges deeply covered with drift, which of course lies yet more thickly in the intervening valleys; but that the band of stratified rocks in which that limestone occurs, runs southward between the Riccarton greenstone and another parallel sheet to the west, is indicated, I think, by the occurrence of this ash at Craigs, and certainly when we cross the great intrusive greenstone boss of Raven Craig, we come upon the ash again with included bands of limestone.

Of these limestones there are two distinct zones, both laid open in quarries at Kirkton. The highest occurs in the west quarry and runs north by Limefield. That it forms the southern prolongation of the Tartraven bed I have little doubt; at least there is no other marine band which could take its place. The lower limestone zone occurs in the East Quarry; and if it be correct to view the higher zone as the equivalent of the Tartraven limestone, then this under one must be regarded as occupying a position somewhere between the Tartraven limestone and the greenstone of the Riccarton Hills; but it is a mere local patch which cannot be traced 100 yards from either end of the quarry, and does not occur in any other part of the county. At the same time its occurrence here is interesting, and the section in which it is seen displays perhaps a greater variety of instructive facts than any locality of similar extent in the district.*

The general section in that quarry is as follows:—The floor is ash, resting on greenstone; above this come various limestones with ashy seams intermingled, then shales and ashy sandstones, while the whole is surmounted by basalt, forming the crest of the quarry. The subjoined woodcut gives a detailed section of the north end of the quarry. The lowest bed is a loose pulverulent concretionary ash (*a*), resting on greenstone; above it comes a thin irregular band of ash-beds and ashy limestones, which last consist of a mixture of felspathic fragments in a grey calcareous base, while some of the ash-beds contain rounded or subangular calcareous stones. A very unequal stratum of limestone (*c*) succeeds; at one point it measures 6 feet in thickness, while a short way off it increases to 13 feet. It is a hard grey

Fig. 12.

SECTION IN EAST QUARRY, KIRKTON (NORTH END).



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* Dr. Hibbert's short notice of this quarry in the Appendix to his Paper on the Burdie House Limestone (Trans. Roy. Soc. Edin., vol. xiii.), though overlooked at the time, and afterwards rejected by Mr. Nicol (Geol. of Scot., p. 92), deserves attention. His explanation of the origin of the Kirkton limestone is undoubtedly in the main correct.

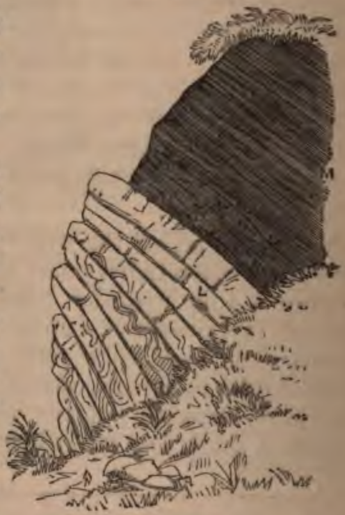
† In both these museums there is a carefully selected series of specimens from the district under review. They were collected under my own superintendence with the view of specially illustrating the nature of these carboniferous igneous rocks.

cherty rock, the chert being either arranged in fine laminæ or in an irregular brecciated or nodular manner. These laminæ often display curious contortions as is well shown by the specimens in the Jermyn Street Museum, London, and in the Industrial Museum, Edinburgh.† Various alternations of ash and limestone occupy the remainder of the section (*d–i*,) until a mass of herbage and débris obscures the slope. Above this we again meet with a limestone (*k*), finely laminated, very fissile; some of the laminæ showing a mamillated surface, while others have undergone great twisting and contortion. Shales and sandy beds (*l* and *m*), somewhat ashy in the upper part, next supervene. They are chiefly remarkable for the great number and beautiful preservation of their included plants, as *Lepidodendron*, *Stigmaria*, *Pecopteris*, &c. A bed of columnar basalt (*n*) completes the section.

If now we turn a few steps south from the point where the preceding section was taken we find a considerable alteration in the beds. The shales (*l* and *m*) become thicker, lose their ashy texture, and contain a good many nodules of clay ironstone. The limestone (*k*) also thickens and undergoes a remarkable series of contortions, which are confined to its mass and do not affect the superincumbent strata. The accompanying Figure (fig. 13) represents the section, shown about the middle of the quarry, where the twistings of the beds sometimes almost reach verticality. The limestone (*l*) is there finely laminated, consisting of alternate layers of silica and lime, which are frequently crumpled and twisted in the most remarkable way, and covered by undisturbed shales *m*.

Fig. 13.

SECTION IN EAST QUARRY, KIRKTON (ABOUT THE MIDDLE).



The succession of events represented by these alternating bands of rock is not difficult to understand. First we have a sheet of lava-form greenstone ejected from some neighbouring orifice, and probably extending over a considerable area. Over the district of Kirkton a small lagoon of fresh or brackish water appears to have formed in a hollow of this lava, so that the next ejection of igneous matter, marked now by the lowest ash seam in the quarry, fell in the form of dust and stones into the water, where, there being no current to assort the sediment, the ash accumulated with hardly any stratification. Over this ashy floor calcareous matter gathered in nodular, irregular bands. Hot springs charged with silica, like those of Iceland, and, like them also, connected with volcanic agencies, seem to have fed the lagoon with water from which the siliceous matter was precipitated, so as to mingle with the lime and form in this way the bands and nodules of chert and the finely alternating interlaminations of silica and lime which are so conspicuous in this quarry. During the accumulation of such silico-calcareous deposits, however, showers of volcanic dust were of frequent occurrence, as is proved by the ashy seams intercalated among the limestones. A change in the physical configuration of the locality appears now to have taken place, and contemporaneously with it a cessation of the deposition of calcareous and siliceous matter. The Kirkton lagoon seems to have become connected with a larger area of water, into which sediment was transported. The upper shales and ashy sandstones of the quarry point to this change of conditions. Their included plants indicate the proximity of land clothed with ferns, stigmariæ, and lepidodendra. But the igneous forces still continued active in the district, as is shown by the quantity of felspathic and ashy material contained among these sandstones and shales, and still more by the great sheet of columnar basalt, an old lava-flow, which overlies the whole series of deposits in this quarry.

This basalt is a dark compact columnar rock, like the other basalts of the district, and probably occupies the whole of the interval westward to the next quarry, where the marine limestone above referred to occurs. That quarry presents many features resembling those of the last, but in place of the remains of terrestrial plants it contains in abundance marine shells and crinoid stems. As with the lower limestone, the basement bed in the west quarry is an ash, fine-grained and disposed in well-marked strata. It contains a bed of greenstone 3 inches thick, of a spheroidal structure; a bed of limestone next occurs, shaley at the base and ashy at the top, where its characteristic *producti* and crinoid joints are especially abundant. At the south end of the quarry these strata are surmounted by ash, then shale, then limestone bands with *Aulophyllum*, *Productus*, *Encrinites*, &c., then by limestone with thin ashy partings, and lastly by a bed of dark basalt, which, like most of the trap rocks of the district, contains a considerable quantity of magnesia. These strata vary very much in a short distance, but they are continuously overlaid by the basalt, which at one part of the quarry rests unevenly on the limestones and ashy seams, where these are broken and intermittent, in a manner not easily explained.

The ancient physical conditions indicated by the deposits of this excavation differ to some extent from those of the east quarry. We see still the same evidences of the ejection of volcanic dust after the eruption of the basalt (*n*, in fig. 12), but in place of the remains of land plants, we have now abundant traces of marine life, *producti*, *spirifers*, crinoids, and corals; showing that the area had undergone a submergence below the sea. The siliceous matter occurs but sparingly, although there is still abundant evidence of volcanic action; the shells and zoophites appearing not unfrequently to have been destroyed by being enveloped in a thickening deposit of ash.

That the limestone of the West Quarry, Kirkton, is identical with the Tartraven bed can hardly, I think, be doubted; and it becomes interesting, therefore, as showing the peculiarly local character of these carboniferous volcanic eruptions, to notice how undisturbed and free from all extraneous ash or greenstone are the limestone and shales at Tartraven and Whitebaulks. Indeed, in working out the geology of this intricate region, nothing was more frequently or more vividly impressed upon me than the markedly local nature of the igneous rocks. Even where we have proof of volcanic activity continuing during a large part of a formation, we can seldom trace the ejections of any single eruption for more than a few miles, and not a single layer of ash or bed of greenstone has yet been detected in the contemporaneous strata of the adjacent county of Edinburgh.

Holding, therefore, that the limestone of Tartraven is identical with that of the west quarry of Kirkton, and that, extending north to the shore near Stacks, they represent a former continuous submarine floor, let us see how the accumulations which subsequently gathered over that calcareous seam varied throughout their course. At Whitebaulks the limestone is surmounted by black shale, above which, if we may judge from the unsatisfactory section east of Cauldhame, comes a series of sandstones, reaching probably to about 80 or 100 feet. These are covered by a remarkable bed of felspathic ash, to which I shall immediately advert. Above the ash comes the thick set of sandstones wherein the Hillhouse quarry has been opened, above which at no great distance, a bed of greenstone supervenes, and then we arrive at the great marine limestone of the Bathgate Hills, where it is exposed in the quarries above the farm of Hillhouse. Let us now compare the section at Tartraven, which is less than two miles south of Whitebaulks. The limestone there also rests below a capping of blue shale, above which for a short way nothing is seen at the surface, till passing over a space equal to a vertical height of probably less than 40 feet we come to the base of a great sheet of greenstone. There is no visible trace of the ash, and if that bed does exist here it must be in a very attenuated form, for there are only about 40 feet to contain all the strata which at Whitebaulks intervene between the top of the limestone and the top of the ash. The greenstone (which at the base passes into a basalt) occupies all the remaining space up to the bottom of the great limestone. The whole of the great Hillhouse sandstones have thus disappeared, and their place is taken by a long sheet of greenstone. If now we pass still southward to the west quarry, Kirkton, 2½ miles from Tartraven, we shall find a still wider divergence from the section at Whitebaulks. The limestone there, as we have seen is itself markedly ashy, is interstratified with layers of ash, and is surmounted by a sheet of columnar basalt. That basalt extends westward for about 100 yards (which with a dip of 20° is equal to a vertical thickness of 100 feet) to near the corner of an east and west strip of wood, where a hollow occurs, in which, as I was informed, a thin bed of limestone was quarried. I saw no rock in place, and the bed is probably a mere local lenticular patch, like that of the lower quarry at Kirkton; with this break the basalt stretches west to the ashy and shaley base of the great limestone, so that here we find the interval between that limestone and the lower or Tartraven seam almost entirely occupied by volcanic rocks, the whole of the sedimentary deposits of Hillhouse having in their southward extension gradually thinned away. Both the limestones rest on ash, the lower one being itself conspicuously ashy, while the interspace between them, with the ambiguous interruption of the thin invisible limestone, consists entirely of greenstone and basalt.

Passing still southward across the flat moory country east of Bathgate, we meet with the limestone again in the bed of the river Almond, below Blackburn; but there the normal conditions are resumed, and we find shales, sandstones, and thin coals, as at Tartraven and Whitebaulks. Hence the area over which volcanic material was ejected here during the accumulation of the Tartraven limestone, cannot have had a north and south extension of more than five or six miles. After the deposition of the limestone, however, ashy matter fell to a considerable depth north of that area, and this ash is quite independent of any of the Kirkton beds. It occurs, as I have said, not far above the quarry at Whitebaulks, whence it swells out northward by Cauldhame to the turnpike road between Kingscavil and Porterside, where a powerful fault occurs, but the ash is again met with westwards at Pilgrim's Hill, at the east end of the town of Linlithgow. It is a dull yellowish or greenish felspathic rock, with pale subangular felspathic fragments at Cauldhame, and at Pilgrim's Hill numerous angular fragments of coniferous wood more or less carbonised. These interesting vegetable relics were noticed many years ago by the late Hugh Miller.*

The Great Limestone falls now to be described, and first let me remark that the term "great" is only applied to it here as marking its local thickness in the Bathgate Hills: southwards it dwindles down into a bed quite as insignificant as that of Tartraven; indeed, one of the characteristic features of this limestone is the way in which it quickly thickens out into a mass of very respectable dimensions, and then as quickly thins away into a band of 8 or 10 feet. It presents the same aspect in the west of Fife.

The most northerly locality in Linlithgowshire where this limestone can be seen is at the lime quarry above Hiltly, at the north end of the long line of the Bathgate Hills. From this point south-west for nearly half a mile an admirable section of the beds is displayed, crowned by an imposing range of basaltic columns. The following is the section near the lime kilns :—

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* "Schools and Schoolmasters," p. 490, edit. 1854.

	FT.	IN.
Surface soil and herbage.		
Columnar basalt.		
Black shale	6	0
Band of irregular gritty limestone.		
Greenstone, soft greenish amygdaloidal	4	6
Siliceous limestone	1	3
Reddish sandstone	3	0
Greenstone, soft white and greenish	1	6
Dark sandy and micaceous shales, with *Stigmaria*	6	0
Limestone	30	0
Shale.		

The strata vary considerably at a short distance some of them disappearing altogether and new ones taking their places,

About one mile and three-quarters to the south, the next opening in the limestone occurs. The quarry is called the "North-mine Quarry," and it forms the beginning of a great range of excavations which indent the hill for upwards of two miles. At the north end of this quarry the following interesting section occurs :—

	FT.	IN.
Greenstone.		
Black shale, altered near greenstone	2	6
Yellowish green felspathic ash, with hard concretionary bands of calcareous ash	5	0
Blueish ash, with rounded pieces of altered sandstone and limestone	4	6
Grey micaceous sandstone, with *Stigmaria* stems	7	0
Coal, with *Stigmariæ* on upper surface	4	5
Fire-clay, with concretionary bands and nodules of ferruginous sandstone.		
Limestone (70 to 80 feet, further south).		

The alternation of coals, fireclays, and marine limestones exhibited in this section is characteristic of the Scottish development of the Carboniferous Limestones. The coal-seams consisting of terrestrial vegetation rest upon beds of fireclay that represent the ancient soils, while the limestones contain corals, crinoids, brachiopods, and many other undoubtedly marine organisms.

In some of the joints in the North-mine Quarry galena occurs, with of course the usual accompaniment of silver. One of these was worked in the time of James VI., by whom the mine was eventually bought; but from the time that it passed into royal hands the ore seems to have almost disappeared. The locality was called the "Silvermine," a name which it still retains. In the rubbish of the old workings a soft pale apple-green arsenurate of nickel occurs in small quantity. I was told, however, that there was quite enough to destroy the domestic fowls of the neighbouring cottage, and that one or two hens which had found their way over the hill from the village of Torphichen never found their way back again.

It is interesting to walk south-west from the Mine quarry, and mark how the strata interchange in their progress below the continuous capping of basalt and greenstone. The ash at the north end gradually thins away, and in its place comes a thick series of sandstones and shales. At the Knock farm a bed of ash is seen underlying the limestone; it is visible also on the road below the cottage south of the Knock Hill, and again in a pretty section at the south end of the Sunnyside quarry. In the north part of that quarry, on the eastern side, I observed a remarkable hole in the limestone. It increases in width as it descends, and is filled with calcareous ash and hardened sand, with large rounded stones. I searched in vain along the upper surface of the limestone for any ash-bed from which material might originally have been washed into this hole. There is a good section for a long way, but it shows only various alternations of sandstone and shale. The sides of the hole are lumpy and rounded, and, at the time, they suggested to me that the cavity may have owed its origin to the erosive action of a strongly acidulous spring possibly connected with the Carboniferous volcanoes. There is a bed of ash below the limestone, but as the top of the hole had been quarried away, and its bottom had not been reached, no point of contact could be observed between the materials filling it and any strata either above or below.

The limestone itself presents a rich assemblage of organic remains, many of which are enveloped or filled with chert, particularly the *Productus giganteus*, while occasionally they contain bituminous matter, possibly the representative of the animal tissues; other characteristic fossils are *Productus semireticulatus*, *P. longispina* (*Flemingii*), *Spirifer trigonalis*.

At Petershill the limestone is from 70 to 80 feet thick. At Redhouse, about 2½ miles south, it is only 8 feet. There are visible on the Almond, near Redhouse, two seams of limestone, each about 8 feet thick, with one or two minor bands. The lower of the two seams has a workable coal below it, and is hence to be identified with what is called the "Main limestone." Perhaps it may also be identified with the Tartraven bed. The following is the section at the Redhouse colliery:—

		FT.
Limestone		8
"Parrot" coal	8 in.	2
"Free" coal	8 "	
"Gas" coal and ironstone balls	8 "	
"Cement," a kind of impure ferruginous limestone		3
Shaly sandstone		10
Coal		4
"Wild Gas" coal		2
Hard brown sandstone.		

There is also a thin coal below the upper limestone, and the shales show the characteristic brachiopods, *Spirifer trigonalis*, *Productus semireticulatus*, &c. No ash or greenstone occurs among these strata, although a short way west, at the Blackburn Bridge, there is a greenstone bed, the southward prolongation of some of the Bathgate Hill sheets. It has a marked magnesian composition, and is quarried as "lakestone," a valuable substitute for fire-brick in ovens.

These limestones are met with on the Breich Water at Addiewell, 1½ mile south of Blackburn, overlaid by the same remarkable greenstone, and they run on by Baad's Mill to Cobinshaw Reservoir; but this part of their course will be more appropriately described in the Memoir to accompany Sheet 31.

To return again to the Bathgate Hills, I have said that the long quarries there are capped by a continuous bed of greenstone or basalt—in some parts, as Hillhouse, beautifully columnar. When we quit the limestone and begin to ascend into the series of which this basalt forms the base, we enter into a confused grouping of greenstones, basalts, and ash-beds, with local lenticular seams of sandstone, limestone, or shale, but with no marked stratum which can give us a definite horizon. We come, in short, to a mass, mainly of igneous rock, which interrupts the connexion of the strata across the country, an interruption, however, contemporaneous with their origin. These huge sheets of volcanic material must have originally risen as a bank, cutting off, at one point at least, the connexion of the Borrowstounness and Bathgate districts. Hence from the great limestone upward to the upper marine limestones, we find no continuous band of sedimentary rock connecting the coal-fields of Bathgate and Borrowstounness. It was not until the progress of subsidence had brought down the quiescent volcanic bank, and by accumulated deposition reduced the sea-bottom to a continuous level, that the connexion was again restored, and a layer of marine limestone (the lowest of the upper limestones) formed over the sea-bottom.

With this preliminary notice it may be most intelligible to describe first the structure of this volcanic bank, that is of the range of hilly ground now bearing the name of the Bathgate Hills, and then proceed to notice the contemporaneous strata at either end which form the coal-fields of Borrowstounness and Bathgate.

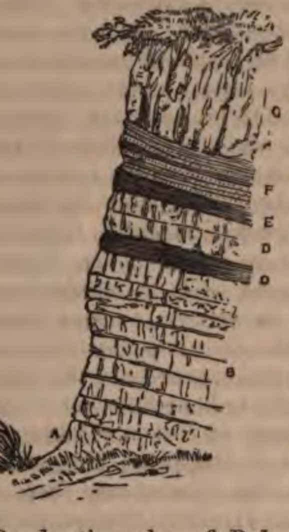
If, beginning at the north end of the hills, we proceed westward from the thick limestone at Hillhouse, we find that the basalt which occupies the crest of the quarries there extends at least to the road leading to Linlithgow. This is a horizontal distance of 2,000 feet, and represents at 15° a vertical thickness of 500 feet of basalt; but the rock probably extends much further than the road, though, owing to the clay and sand covering the eastern slopes of Cocklerue, no rock can be seen. In the stream at Preston House, however, which is only three-quarters of a mile to the north, there is a well-marked interstratification of dull green granular felspathic ash, with rounded trap fragments. It probably does not reach 30 feet in thickness, and is covered and underlaid by greenstone. This bed, if it extends so far south, should occur somewhere about the reservoir at the head of

Preston Burn; but we see there nothing but drift clay and a thick boggy vegetation, from which protrude some weathered boulders of greenstone. Proceeding still westwards in ascending section, we find under the south-eastern crest of Cocklerue some precipitous crags of greenstone, the prolongation of the beds overlying the ash at Preston Burn. These are surmounted by some pale sandstone and a seam of sandy ash, which dip below the greenstone that forms the picturesque summit of the hill. This interpolation of stratified matter among these lava-form traps cannot, unfortunately, be traced towards the north, owing to the obscuration caused by the drift and the want of natural sections. It swells out southward, however, and is seen in the quarry south of Kipps. Here the lower coals of the Bathgate field begin, and, with their associated sandstones and shales, stretch southward, between sheets of greenstone, to Cathlaw, thence to Hilderston (where two of the coals are seen in a sandstone quarry), and so by Ballencrieff to Bathgate. These coals fall to be described in a subsequent memoir; they are mentioned now only to show the position of the ash and sandstone at Cocklerue. It appears then, that, taking a section at the north end of the chain from the Great Limestone at Hillhouse to the horizon of the lower Bathgate coals at Cocklerue, we find the whole of that thickness to consist apparently of greenstone, with the exception of the thin intercalation of ash at Preston. This may be taken as the point where the mass of igneous rock is thickest, and it is here and northwards that the connexion between the Lower Bathgate and the Lower Borrowstounness coals is interrupted. The ash and sandstone at Cocklerue, as we try to trace them north, are soon lost, and we find ourselves in a hopeless chaos of greenstones and basalts, with the additional obscurity of the drift. The band of sandstones and coals, which is about 300 feet thick at Balbardie, near Bathgate, does not reach 40 feet at Cocklerue, and apparently loses all its coals, while it disappears altogether before reaching Kettlestone, and then the greenstones form a bank, in which I in vain searched for any stratified intercalation. But these greenstones rapidly thin away to the north. There is no evidence that they reach Longcroft House; on the contrary, the coals and sandstones reappear there, having been found in some deep wells at the paper-mill. From this point we ascend towards the north-east, and along the southern slopes of Glowerowrem Hill meet with the old workings in the Lower Borrowstounness coals. The area of discontinuity, therefore, must lie between Longcroft House and Cocklerue. North of that area we have the regular lower coals of Borrowstounness graduating downwards to the thick limestone, and south of it the lower coals of Bathgate, while the area itself consists of a confused assemblage of greenstones, probably of various ages, the product of eruptions contemporaneous with the strata at either end, as we shall immediately see.

Such being the character of the rocks superimposed upon the thick limestone at the north end of the Bathgate Hills, let us trace their variations southward. On the farm of Balvormie, a bore was put down in the year 1834, which passed through a number of alternating sandstones and limestones, probably a continuation of the Hillhouse beds. At Wardlaw, about a mile south by west, we meet with a limestone higher than the thick seam. It was worked both here and on the east side of Cathlaw Hill, but has not been seen either to the north or the south. It is another of those local lenticular seams of limestone to which I have already had occasion to refer; but it differs from every other limestone in the district, in the great abundance of its *Lithostrotion irregulare.* The close set stems of that coral constitute entire layers of the rock. The following woodcut represents the section displayed in Wardlaw quarry. The lowest bed visible is a light greenish magnesian amygdaloidal greenstone (**A**), on which the limestone (**B**), about 15 feet thick, rests directly. The bottom of this limestone (*l′*) consists entirely of closely segregated stems of the lithostrotion, which being held only loosely together, crumble down into heaps resembling broken pipe stems. Another more compact bed (*l*) occurs near the top of the limestone, and varies from 10 to 15 inches in thickness. The next stratum is one of dark compact shale (**C**) nearly 2 feet thick, and this is covered by about 2 feet of impure shaly limestone (**D**) with shaly bands. Three or four inches of black compact pyritous shale (**E**) lie above the limestone, and then a thick bed (about 5 feet where the section was made, but it decreases southwards,) of dark sandy shale (**F**), with *Calamites*, *Producti*, scales of *Palæoniscus*, &c. As usual the quarry is crested by lava-form trap—here a greenstone (**G**) in irregular lenticular laminæ from an inch to a foot in thickness, having a pisolitic or amygdaloidal structure. This greenstone passes up into others of the usual texture, which stretch westwards until they are overlaid by the sandstones and coals at Kipps already alluded to.

Fig. 14.

SECTION IN WARDLAW QUARRY.



This limestone, with the great sheets of greenstone underlying and overlying it, passes south above Upper Craigmailing to Cairn-naple Hill, the highest of the range.* But here we begin to observe a marked change in the greenstones. They become greatly narrowed and split up by intercalations of sandstone, shale, &c. The change begins on the hill south of Cairn-naple, and is characterized on the surface by the long narrow hollows caused by the wearing away of the strata between the harder beds of trap. Unfortunately there are no sections by which the nature of these stratified intercalations can be ascertained. If, however, we examine the Mavis Glen to Petershill, about one mile south of the hill last mentioned, the detailed structure of the ridge will at once appear. The thick limestone, as displayed in the large quarries of Petershill, is covered by a considerable thickness of sandstone and shale, which reach to the top of the excavation and a short way west, until they dip below the greenstone. The latter rock extends to about the farm-steading of Brightknowes, where if the soil were removed we should probably find a thin interstratification of yellow sandstone, which may be inferred from the evidence supplied by the bank above the Academy. Another greenstone band then supervenes, and from this point we have a complete ascending section in the Mavis Glen to a vertical extent of fully 400 feet. 1st. The lowest beds there visible are sandstone and shales surmounting the greenstone last mentioned and above them the following beds are seen in ascending section. 2nd. Hard blue compact greenstone in a bed from 40 to 50 feet thick. 3rd. Bed of fireclay containing balls of amygdaloidal greenstone, some of which measure 3 feet in diameter. 4th. Coaly shales. 5th. Light green hardened shale. These three beds of stratified rock may together amount to, say, 20 feet. 6th. Greenstone bed between 130 and 150 feet thick, very amygdaloidal and vesicular towards the top. 7th. Sandstones, shales, thin coals, and at least one minor bed of greenstone,* amounting in all to perhaps 130 feet, and surmounted by the "Main coal," the crop of which crosses near the junction of the Glenmavis road with the turnpike road, as is shown by the remains of an old crop-pit close to the east side of the road in the first field north of the houses.

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* The summit of Cairn-naple Hill is 1,498 feet above the sea.

This section clearly shows that the great sheets of greenstone so conspicuous towards the north end of the Linlithgow Hills are thinning off southwards. Accordingly, although they occur in the district between Bathgate and the river Almond, as is shown both by one or two protruding exposures, and by a series of mineral bores, only one greenstone bed,—the "lakestone," above referred to,—appears to cross that stream.

The "Main coal" lies at the base of the Balbardie coals, and these represent the coals of Borrowstounness. They are covered by another sheet of greenstone, and then, without the intervention of farther igneous rocks, the series becomes regular, passing up into the upper marine limestones, and thence into the Upper coals of Bathgate, which lie on the same horizon as the "Flat coals" of Mid-Lothian

The details of the Bathgate Coal-field fall to be described in a subsequent Memoir. It is at present enough to point out that the coal-bearing measures of Balbardie, reaching to between 300 and 400 feet, extend northwards by Hilderston and Cathlaw to

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* Found in a bore.

Kipps, and that they are surmounted for the whole of that distance by the Balbardie greenstone, which towards Kipps becomes greatly enlarged, and takes the form of a compact, occasionally columnar, basalt. From Kipps this basalt keeps northward by Threegables, joining there the greenstone of Cocklerue, and then sweeping north-west to Kettleston Hill. It is here, as I have stated above, that the Bathgate coals die out, and their place is taken by these sheets of contemporaneous lava-form trap. The discontinuity of the two coal-fields is effected by the upward prolongation of the greenstones forming a bank, against which the attenuated Bathgate series abuts on the south side and the Borrowstounness series on the north.

Above the basalt of Kipps the carboniferous strata recommence. Between Kipps and Linlithgow Bridge they contain one or two large lenticular sheets of greenstone, and north of Gormyre, a bed of dull green calcareous felspathic ash; but their characteristic feature is the occurrence of two seams of limestone,—the upper marine limestones before alluded to. These two calcareous bands are well seen on the banks of the river Avon at Carribber, whence they range north to the shore west of Kinneil, and south by the western suburbs of Bathgate to Leven Seat. Here then is a definite horizon. These beds cover over the trappean ridge and extend into both the coal-fields, so that with them as an upper limit and the thick limestone as a base, we can compare the variations of the intermediate strata throughout the district.

It appears, therefore, that the great ridge extending from Bathgate to Cocklerue is eminently trappean throughout its whole extent. At its southern end it contains limestones, shales, and sandstones only as occasional intercalations, while the main mass of rock consists of basalts and greenstones, with layers of ash. Advancing northward, we find these statified intercalations becoming fewer, and the lava-form traps consequently thicker, until at the north end of the chain the whole series, from the thick limestone of Hillhouse up to the upper limestone of Bowden Hill, is so thoroughly trappean that we can detect in it only two thin intercalations of sandstone, together not a hundred feet thick. One of these is the bed on the east side of Cocklerue, the other lies 200 yards west of Threegables. It is possible to estimate roughly the thickness of igneous rock here. A line drawn due east from the limestone of Bowden Hill to the thick limestone at Balvormie Cottage measures rather less than a mile and a half, about 7,000 feet. The dip of the rocks at the east end of this line is as high as 40°, near the middle it is 20°, and at the west end 13°. Taking 20° as the average, we get a total thickness of rather more than 2,300 feet, of which 2,200 are probably trap. And let it be remembered that this section is taken at by no means the broadest part of the trappean ridge. On the contrary, the line indicated is drawn across just before the trap takes the abrupt westerly turn to the Almond below Carribber, from which point east to Hillhouse the trappean ridge has a breadth of more than 2 miles. I am aware that in such calculations regard must always be had to the possible concealment of beds by the superficial soil and drift. In this case some intercalations of stratified material may exist unseen, but their extent is probably not great; and, judging at least from the intercalations that do occur, they are most likely to consist, in a large proportion, of ash.

Having now pointed out the general distribution of the beds between the great limestone and the upper limestone at the south end of the trappean ridge, it remains to describe the relation of the beds at the north end, where they swell out into the coalfield of Borrowstounness. I have already remarked, that the greenstones thin away rapidly as they approach Linlithgow, and that the coals reappear somewhere in the neighbourhood of Longcroft House. The greenstone occurs all along the south side of the town of Linlithgow, but there is no evidence that it crosses the loch. The coal-bearing strata come in in a wedge-shaped form, thickening along the south of Glowerowrem Hill, and thence into the coal-field of Borrowstounness. The trap which covers the upper part of that hill and extends to the shore may perhaps be connected with the highest beds of the Cocklerue ridge, but the point of connexion is obscured by a thick covering of sand and coarse gravel which fills the valley of Linlithgow westward for several miles. Above this trap another wedge of coal-bearing strata occurs which swells out northwards to form the upper part of the Borrowstounness coal-field. These upper coals are covered by the upper marine limestones, and this may give a good illustration of the discontinuity of the Borrowstounness and Bathgate coal-fields, for the whole of the upper and lower series of the former disappear and do not cross the trap-ridge, while the upper limestones with their associated strata rest directly on the trap.

The coal-bearing measures of Borrowstounness, like those of Bathgate, repose upon the lower limestones of the Carboniferous Limestone group, and are surmounted by the higher. But while in the latter coal-field the underlying limestones have been laid open in an extensive series of quarries, their position below the former can only be conjectured, since no natural section, no quarry, and no mining bore reveals their position.

The last place where the thick limestone is seen in its northward progress is the quarry of Hillhouse. We find blocks of it, however, as stated above, on the shore below Stacks, and these are probably not far out of place, seeing that exactly opposite, on the Fife coast, the limestone appears in great force. The dotted line on the map between Hillhouse and Stacks represents the probable line of outcrop of the limestone, as far as it can be determined from the evidence on the surface, and from bores for coal on the estate of Springfield. The greenstone and basalt which run north from Hillhouse to Linlithgow are undoubtedly the same rocks which overlie the limestone at the former locality, and hence their eastern edge must very nearly correspond to the outcrop of the limestone. We have evidence of their base at the

Poor House, where a thin coal-seam along with some sandstones was found in digging for a foundation, and a coal, possibly the same as the last, was cut through in sinking a well at Hillside Cottage. These strata correspond in character and position, to those which at different points overlie the thick limestone. North of the town the greenstone disappears, and we obtain no section along this horizon until we come to the shore east of Carriden House. Proceeding westwards from the limestone blocks of Stacks, the first stratum visible on the shore is a thin bed of coarse calcareous grit, the upper surface showing the *Cauda Galli* or "Cock-tail" markings, believed to be the impressions of sea-weeds. Some shales with fragmentary shells are associated with this grit, and above them comes a thick mass of well-marked felspathic ash, forming the high bank between Carriden House and the sea, and laid open in a deep ravine by the Carriden Burn, Ascending that rivulet we have a good section of the strata above the ash. There are first some fissile carbonaceous sandstones and shales, also seen in the quarry on the shore, and about midway in that series occurs a band about 1 foot to 1½ foot thick of coarse limestone full of small encrinites. No further strata are visible in the glen, but there are some old crop-pits, marking that we have entered into the series of workable coals.

CHAPTER VII.

CARBONIFEROUS LIMESTONE OF LINLITHGOWSHIRE—*continued*.

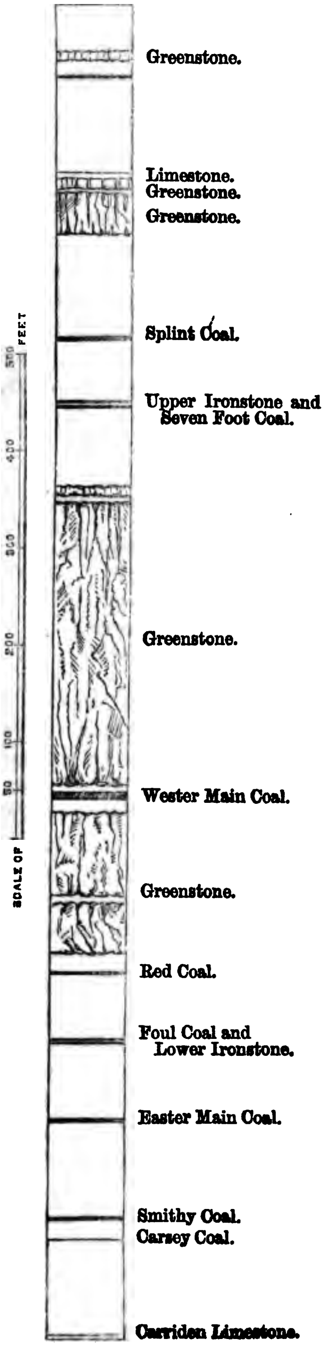
BORROWSTOUNNESS COAL-FIELD.

THE Borrowstounness Coal-field, lying as it does between the thick limestone that crosses from Hillhouse to Charleston, and the upper limestones already referred to, unequivocally belongs to the Carboniferous limestone series, and occupies the same horizon as the Edge coals of Mid Lothian. Though of small extent, and subdivided by sheets of hard trap-rock, this coal-field has been worked for centuries. It consists of two series of coals, separated by a sheet or rather series of sheets of greenstone that make a total thickness of nearly 400 feet. This rock does not affect the quality of the coals, and throughout the coal-field the pits are invariably sunk through less or more of it to reach the seams below. The subjoined section gives a generalized view of the strata forming the Borrowstounness Coal-field.

The lowest coal in the series is the Carsey coal, a coarse seam which has never been worked, although some of the crop-pits in the grounds of Carriden House may have been opened in this seam. The Smithy coal averages about 3 feet in thickness, but is not now worked. In the deep boring at the Snab pit it was 2 feet 10 inches thick, resting on the ordinary sandstone pavement, and covered by shales which extend throughout the coal-field with a thickness of about 20 feet. The Easter Main coal averages about 4½ feet in thickness, and occurs from 70 to 130 feet above the Smithy coal, the intervening strata being chiefly shales and thin-bedded sandstones, with a sheet of greenstone at the Carriden Manse. It has a sandstone pavement and roof, the latter being a bed from 60 to 70 feet thick, very persistent throughout the entire field.

Fig. 15.

SECTION OF THE BORROWSTOUNNESS COAL-FIELD.



The next seam is the Foul coal and Lower ironstone, now worked solely for the latter. The Foul coal consists throughout the field of several seams, with bands of ironstone and fireclay between. At No. 9 pit, about 180 yards north of Bonhard House, this seam is composed as follows:—

		FT.	IN.
	Shale - - -	10	0
	Coarse ironstone -	1	6
	Shale - - -	3	0
"Foul coal."	Foul parrot coal -	6	8
	" Brown-stone " ironstone - 10 in. to	0	3
	Sandy fireclay 2 in. to	0	3
	Parrot coal - 8 in. to	1	6
	" Black-stone " ironstone (inferior in quality) - 8 in. to	0	10
	Dross coal - -	0	6
	Coarse fireclay 9 in. to	1	0
	Dross coal 2 ft. 2 in. to	2	6
	" Calm " - -	0	9
	Black hard shaly sandstone - -	0	9
	Dross or Foul coal -	1	6
	Sandstone above Easter Main coal.		

The inferior quality of this seam has given rise to its name.

The "Red Coal" lies from 80 to 108 feet above the Foul coal, the strata between them being shales and sandstone bands. It varies from 2 feet 9 inches to 3 feet 4 inches in thickness, lies on a bed of "fakes," or shaly sandstone, and is surmounted by strata of a similar character. It is not now worked.

Above the Red coal there is in the east part of the field a depth of from 25 to 30 feet of shaly sandstones and shales, and then succeeds a great sheet of greenstone 110 to 150 feet thick, which extends throughout the entire coal-field, and has been pierced in all the pits sunk to the Lower ironstone. Although it is mapped and described as one sheet, from the impossibility of tracing the intercalated strata which subdivide it, it in reality consists of several sheets at least in the east part of the coal-field. Thus, in the Kinglass Engine pit, it consisted of three zones, the upper (about 20 feet) separated by some 30 feet of shales from the lower beds, which again had between them a thin intercalation of very hard sandstone, called "red-stone." In the Snab pit, a coal which from its position in the section appeared to be the Red coal, was found to be surmounted by one undivided sheet of greenstone, 91 feet 6 inches thick.

	FT.	IN.
Shale.		
Greenstone	91	6
Coal	0	6
"Calmstone"	1	4
Coal	1	2
"Fakes"	1	6
Greenstone	4	6
Sandstone	16	3

In this section another greenstone occurs below the Red coal, and it may be remarked generally that the aggregate thickness of the traps is greater in the deep sinkings in the west part of the field than towards the east.

An average thickness of about 30 feet of various strata intervenes between this lower greenstone and an upper sheet. The most important member of this intercalated group is the Wester Main coal, a seam which was formerly extensively worked, since it reached to a thickness of sometimes 12 feet. It in some places appears to rest directly on greenstone, and is even occasionally covered by it as in the tramway east of Burn pit. More frequently, however, it has a sandstone roof and a superincumbent thickness of 15 to 20 feet of shales and shaly sandstones. Towards the dip, that is, westwards, it dies away altogether, and in the Snab pit section its place was found to be occupied by about 13 feet of black shale, immediately covered and underlaid by the trap. Hence the Wester Main coal has now been entirely exhausted.

The upper greenstone, like the lower, consists, eastward, of more than one sheet, but its subdividing shales, &c. are not persistent. In the Snab pit section, the shales which represent the position of the Wester Main coal are overlaid by one continuous sheet of greenstone, 265 feet thick, which was cut through at an enormous cost, in the hope of reaching the yet untouched portion of the thick and valuable coals that crop in the east part of the field. But the Wester Main coal, as just remarked, was found to have disappeared; there was no Lower Ironstone, and nothing else of sufficient value to repay the cost of extraction. In No. 3 pit, where another deep sinking was made with a similar design, although the ultimate success was no better, some curious facts were discovered. In the descent, the usual strata, sedimentary and igneous, occurred, and at length, though sooner than had been anticipated, the top of the thick greenstone was reached. It was pierced to a depth of 150 feet, when a series of sandstones and shales succeeded, containing what was believed at the time to be the Wester Main coal. The stratified beds formed an intercalation of about 30 feet, below which greenstone was again bored through to a depth of 138 feet. Here the auger struck upon a rich seam of coal, 9 feet thick, supposed to be the Red coal, though if so it certainly lay much higher in the series than in any other part of the field. The pit was accordingly deepened to this valuable winning, and the coal began to be worked. The quality proved to be excellent, although covered and underlaid by the greenstone. But in a very short time it was discovered that the seam formed a mere local layer, filling an irregularly circular hollow in the lower greenstone, and though mines were driven into the contiguous rock in several directions, no trace of coal could be found. The boring was, therefore, resumed, but after passing through an apparently interminable thickness of greenstone, the pit was finally abandoned.

The occurrence of this lenticular patch of unaltered coal between sheets of lava-form trap affords an interesting corroboration of the inference deducible from the surface geology, that the igneous rocks of this dictrict date their production from the same period with the formation of the coal-field. There would seem to have been a depression on the surface of one of the subaqueous lava streams, where vegetable matter accumulated prior to the next ejection of igneous matter. The absence of metamorphism along the upper surface of the coal, though remarkable, is not inexplicable, more especially when we remember how trifling is the alteration produced on coal-seams by undoubtedly intrusive rocks in not a few parts of the Scottish Carboniferous area.*

The 265-feet greenstone of the Snab pit, after a capping of 5 or 6 feet of shale, coal, and sandstone, is succeeded by another greenstone about 20 feet thick, after which come the regular strata of the upper series of coals of the Borrowstounness field.

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* I know of no more beautiful and convincing proof of this than is afforded by the section in an old quarry at the Townhill colliery, near Dunfermline. A bed of greenstone has there insinuated itself between a bed of coal and some shales and sandstone, yet the coal has been worked with the greenstone for a roof, and worked, too, up to the surface, as the old mine at the west end of the quarry admirably shows. The coal is a little hardened, but certainly not charred, while the greenstone seems to have suffered more from the contact than its neighbours, its centre being firm, compact, and faintly crystalline, while the upper and under surfaces have an earthy, decomposing texture.

Of these the lowest of importance is the "Seven-foot Coal" and "Upper Ironstone," which lie about 60 to 70 feet above the last greenstone. In the Snab pit these two seams show the following intercalations:—

		FT.	IN.
	"Fakes" (shaly sandstone)	20	8
	"Blaes" (shale)	3	0
	Coal	1	2
	Blaes	0	3
	"Marled Stone"	0	6
"Upper Ironstone"	Ironstone	1	5
	"White Stone"	0	6
	Blaes	4	4
"Seven-foot Coal"	Coal	2	0
	Blaes	0	4
	Coal	2	6
	Fireclay and Blaes	6	6

The most valuable part of this section is the ironstone, although its quality falls short of that of the Lower Ironstone. It crops on the shore about 120 feet west from the parish church of Borrowstounness; thence it stretches south to Newton, beyond which, though its position continues, the ironstone itself dies out, its place being taken by coal and shale. This rapid attenuation or sudden disappearance is a phenomenon much more frequent among ironstones than coals. A coal-seam can often be traced in unbroken continuity over a wide extent of country; but a black-band ironstone seldom occurs in the Scottish coal-fields other than locally. It occupies an irregular area, which does not depend on the present configuration of the rocks, but must have had the same definite outlines during the formation of the seam. The ironstones are commonly associated with *parrot* or *cannel coal,* into which they very generally pass along their outer limits. After an interval occupied by coal and shale, the ironstone may come in again in another irregular patch, and this may go on even over an entire coal-field. But the identification of two ironstones in different parts of the country, merely from their general agreement in stratigraphical position, is not always safe. The only stratum in a coal-field where such an identification can usually be made with some approach to certainty is a band of marine limestone, especially those bands which have been already referred to as overlying the coals of Borrowstounness and Balbardie, and separating these from the Upper Coals of the Linlithgow and Stirling basin.

After passing over two or three unimportant seams of coal, we come to the "Splint Coal," from 100 to 120 feet above the Upper Ironstone. Its average thickness is about 2 feet 4 inches, though in some places, as in the Snab pit, it has a lower impure seam of a foot or less in thickness. It rests on a thin seam of fireclay, and is surmounted by shale. Like the Upper Ironstone and all the seams above, it lies entirely in the west half or upper division of the Borrowstounness field, since its crop rises to the surface in the old graveyard on the shore west of the town of Borrowstounness, whence it ranges south towards Linlithgow.

In the Snab pit, about 140 feet above the Splint coal, lies a seam of limestone 15 or 16 inches thick, containing *Productus giganteus* (small variety) and crinoid stems—a marine band. It is seen also at the entrance to the fireclay workings at Kinneil. In the interval between the coal and this limestone a band of greenstone occurs, which at the Snab pit measured 51 feet thick; a quarter of a mile north-east, at pit No. 24, 50 feet; at pit No. 3, half a mile south of the last, also 50 feet. This seam of igneous rock, like those already noticed below it, produces no deterioration in the quality of the adjacent minerals. In the Snab pit its upper surface has a covering of between 8 and 9 feet of shale and foul coal, above which comes another band of greenstone 5½ feet thick. It must be either this upper bed, or the lower one very much diminished, which occurs in the subjoined section, taken at the rocky bank by the roadside to the east of the Kinneil distillery.

Clay and soil.
Impure limestone, 2 ft. 3 in. (encrinites, producti, &c.)
Fireclay and shale.
Fissile sandstone.
Shaly fireclay.
Band of hard ferruginous grit.
Greenstone, 6 or 8 feet.
Coarse quartzose sandstone (indurated atop).

The limestone in this section is the same as that of the Snab pit, and is also seen at the mouth of the fireclay excavations. It has been found in the same relative position as regards the greenstone in pits No. 24 and No. 3.

The fireclay to which reference has just been made is about 3½ feet thick, and overlies the limestone. It is extensively mined for the purpose of making fire-brick, &c.

The bed which covers this fireclay occupies, from its dimensions and peculiar aspect, a conspicuous place in the measures of this western part of the coal-field. It is a yellow quartzose sandstone, soft and easily worked, occurring as one undivided bed 79 feet thick. It forms the roof in the fireclay mines, and extends westward from the distillery to the back of the iron works as a low cliff, once the upper limit of the old coast line.

A coal about 2 feet thick, with a thin shale parting in its centre, lies about 14½ feet above this sandstone; and this is the last of the seams laid open by the deep section of the Snab pit.

The Splint coal is the highest of the valuable seams in this coal-field. The strata which overlie it have been bored in many places, but no continuous section has been made between it and the Upper Limestones, and the actual thickness of intervening strata is therefore unknown. Measured across the strike of the beds, the space between the outcrop of the Splint coal and that of the lowest of the upper limestones occupies a mile, and this at 7° gives in round numbers a vertical thickness of 650 between the two seams. But the actual depth of strata must be more than this calculation would indicate, for the bores that have been put down to the west of the Snab have not reached the Snab pit seams, though carried quite deep enough to have done so had the dip of the strata continued regular. On the whole there seems a probability of a line of fault running from south-east to north-west, and crossing the shore near Kinneil House—a conjecture which had also occurred to Mr. Begg, the manager of the Kinneil Ironworks.

Some thin seams of coal have been mined in former times to the west of Kinneil, but no record appears to remain of the workings. In the bores put down by the Kinneil Iron Company to test the nature of the strata between their Splint coal and the lowest or Dykeneuk limestone, nothing in the form of coal was obtained, save some impure bands never more than a few inches thick. In the most easterly of the bores, which was sunk at the Deil's Kitchen, west of the north gate to Kinneil House, a depth of 300 feet was bored through without meeting with a single seam of coal.

Only a very few words are needed in explanation of the outcrop and faults of the seams in the Borrowstounness Coal-field.

The lower seams, *i.e.*, those below the great dividing zone of greenstone, after following a sinuous course in an E. by S. direction along the declivity from the town of Borrowstounness to Carriden Church, trend towards the south, and following still the curves of the greenstone hills, sweep southward along the eastern flanks of Bonnytoun Hill, until they are lost in the trappean region beyond Linlithgow Loch.

The greenstone beds take the same direction. They form the higher ground between the sea and Linlithgow, and can be traced with certainty to the south-west end of Bonnytoun Hill, near Balderston. South of this point the enormous depth of sand and gravel which supervenes prevents any rock from being seen. The greenstones however seem to pass below the ash of Balderston, whence they probably stretch across the valley of Linlithgow to join the masses of Kettleston.

The upper coals of Borrowstounness all crop to the west of the town. From the shore they are worked for rather more than a mile to the south. Beyond this there is a great lack of information, from the confused and unsatisfactory results of the bores. The whole of the series appears to be rapidly thinning out towards the great trappean region, and hence it becomes almost impossible to identify seams in the bores even at short distances. The coals which have lately been found above the ash at Balderston would seem from their position (only a short way below the Dykeneuk Limestone), to be higher than any of the Snab seams, but in that case these latter seams must have entirely thinned away. It will be impossible to speak with certainty upon these points until more detailed information is obtained regarding the ground between Borrowstoun Mains and Balderston. In the meantime there can be little doubt that the ash of Little Mill and

Balderston, extending from the river Avon to the south-west flank of Bonnytoun Hill must occupy the place of nearly, if not quite, the whole of the upper series of Borrowstounness. Its base approaches within a very short distance of the greenstones which underlie the upper coals, and its top is almost immediately below the lowest of the upper limestones, and its entire thickness probably falls short of 300 feet. Here, then, in the short space of 1¼ mile a great series of sandstones, shales, fireclays, and coals, in all more than 1,100 feet thick, has disappeared, and in its place we find a bank of volcanic ash, with some underlying sandy beds resting on a lower group of greenstones.

Above this ash, and only a few feet below the limestone, a thin parrot coal, with some nodular black band ironstone, is seen on the banks of the Avon, between the Avon Print Works and Linlithgow Bridge. But it can have no connexion with the Upper Ironstone of Kinneil, and though mined with the expectation that it would prove of value, the workings were speedily abandoned. It is only another of those local patches of ironstone to which reference has already been made, as sufficiently common in the carboniferous basins of Scotland.

The faults by which the Borrowstounness Coal-field is traversed are numerous, but none of them attain a throw of more than 120 feet, and the vast majority are mere local hitches of a few inches, and occasionally of a few feet. They may be considered as in a general way trending east and west, or rather E. by S. and W. by N. In all the larger dislocations the downthrow is invariably to the north, and the effect of this, as will be shown in a subsequent chapter (Chap. XII.), has been to lower the whole field to the north by a gradual step-like series of depressions.

On the mining plans of the old submarine workings a fault, said to have a downthrow to the north of 17 fathoms, is drawn from the end of Bridgeness Pier towards the mouth of the harbour of Borrowstounness. Parallel to this line another dislocation of 14 fathoms (also to the north) extends from the sea east of Carriden Manse, westward by the foot of the slope behind Grangepans, and thence through Borrowstounness to the sea. The effect of this fault is, that the greenstone from the top of the slopes is brought down to the shore, and thus seems to dip below the coals, which crop along the declivities from the town to Carriden. Between this fault and North Kinglass several other faults, with innumerable minor hitches, occur, having the same general direction, but their throw does not exceed 30 or 35 feet, and usually falls much short of this extent. In the Chance pit workings a hitch with the W. by N.—E. by S. strike depresses the ironstone 14 feet to the south, and eastwards the subsidence increases to 20 or 25 feet. At North Kinglass a cross fault occurs, striking E.N.E. and W.S.W., which throws the strata 30 to 35 feet down to the south. Between Muirhouses and No. 6 pit a fault with the prevalent strike depresses to the south 30 feet and dies off to the west. A good instance of the effect of these faults on the surface, when that is not denuded or obscured by drift occurs along the tramway at Doghillock. A marked, though low, escarpment of greenstone runs there in a due east and west direction, and would undoubtedly at first sight be set down as the side of an intruded dyke. In reality, however, as disclosed by the subterranean workings, this escarpment arises from a small fault which has depressed the beds along the north side to a depth of 12 feet. The superior permanence of the outstanding greenstone has enabled it in some measure to withstand the old denuding agencies, and hence the undepressed side still rises in a conspicuous ridge above the other.* Another though less marked instance is exhibited by the most powerful fault in this coal-field. This dislocation has the usual strike, and runs along the valley from Bonhead Mill westward by the north side of Bonnytoun Hill. Its amount at the west end in a line due south of the Burn pit must be at least 120 feet of downthrow to the north. To this subsidence is due the rapid descent of Bonnytoun Hill into the valley on its north side.

Upper Marine Limestones.—Reference has often been made in the preceding pages to two seams of marine limestone which overlie the trappean ridge of the Linlithgow Hills, and likewise the coals of Balbardie and Borrowstounness. They form the closing part of the Carboniferous Limestone series not in this county alone, but apparently over a considerable extent of central Scotland. They occur (as three bands) in the Edinburgh coal-field on the east (*see* Chap. 8, pp. 73 and 75), extending north into Fife, and westward into the coal-fields of Stirling and Lanark.

The relative position of these limestones above the Borrowstounness coals is well shown along the old coast line west of Kinneil. In the railway cutting near Dykeneuk the lower seam occurs in three bands with shales between, the whole having a thickness of about 7 feet. The strata both above and below consist of shaly sandstones, shales, and thin coals. From this point it runs south through Kinneil Wood to the River Avon above Kinneil Mills, where it occurs in the ravine of a small rivulet descending from the north. It then trends to south-east crosses the Avon again at Little Mill, bends south-westward and recrosses the stream below Linlithgow Bridge. It keeps the Stirlingshire side of the Avon until it crosses at Woodcockdale House, and after once more passing to the west side below Muiravonside, it finally trends into Linlithgowshire below Easter Carribber. Its southward progress, however, cannot be further ascertained, and there appears reason to believe that this lower seam never formed completely over the Cocklerue ridge, and that hence its outcrop is interrupted.

One or two sections in which this limestone occurs deserve notice. Where it first appears on the Avon a little above the mills it is underlaid at a short distance by a thick bed of green felspathic ash, admirably exhibited in the cliff below Little Mill This rock presents the usual features, and contains large bombs and smaller balls of basalt and greenstone, with fragments of what seems an older ash. Another characteristic section occurs higher up on the right bank of the Avon near Easter Carriber. A peculiar greenish mudstone occurs a short way below the limestone, containing *Productus giganteus*, *Strophomena crenistria*, *Fenestella*, *Aulophyllum*, &c. The limestone itself lies in a triple band in the cliff, of which the subjoined table gives the details :—

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* *The tramway at this* point shows the interesting section of the Western Main *coal overlaid by greenstone,* referred to on a previous page.

	FT.	IN.
Dark sandy shale.		
Impure limestone	0	6
Dark shale	0	6
Compact limestone	3	0
Shale parting.		
Limestone	0	8
Dark shale.		

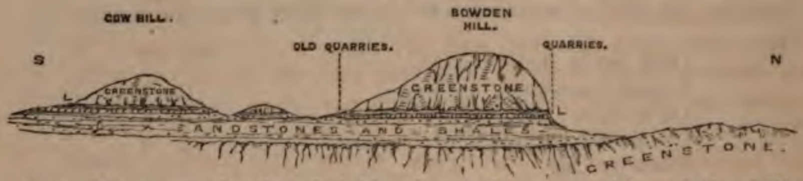
The strata between the two limestones consist of sandstones, shales, and some thin seams of coal. They are well seen along the railway west of Dykeneuk, also in the Avon, below Kinneil Mills. One of the most noticeable beds is a coarse gritty sandstone, immediately below the upper limestone, quarried at Craigenbuck and exposed at the Avon above the railway viaduct. It appears to thin away southwards, and indeed the two limestones approach much closer to each other at Carribber than on the shore. This is not alone due to the higher angle of dip at the former locality, but also in part to a general decrease in the thickness of the intervening strata.

The upper limestone has a thickness of 7 or 8 feet. It may be seen in the old quarry at Craigenbuck. Thence it ranges south to the viaduct over the Avon, where it is at present quarried for the Kinneil blast furnaces. The seam there exposed is about 7 feet thick, lying between two masses of shale, and with a thin shaly parting. It occurs at the canal aqueduct over the Avon, and crosses into Linlithgowshire again at Carribber, where it dips below the great sheet of greenstone forming Bowden Hill and the range of hilly ground southward to Torphichen. The section on the side of Bowden Hill above the quarries is as follows :—

	FT.	IN.
Greenstone, forming the upper part of the hill.		
Soft white shaly sandstone	1	3
Harder sandy bands	0	6
Coarse calcareous bands, very hard, siliceous, and nodular	1	5
Coarse sandy limestone, more sandy towards base, about	6	0
Brown and grey sandstone	7 to 8	0
Blue shale	1	6
Blackish sandstone	3	6
Thinly laminated shaly sandstone, with plants	1	4
Dark blue shale, with a hard band	1	4
Upper Limestone :		
Black, very hard, shaly limestone	1	4
Hard, compact, grey limestone	7	0
Nodular seam of sulphate of barytes.		
Shale.		

Towards the base of the limestone detached cubes of iron pyrites are abundant, and a seam of sulphate of barytes forms the pavement. The limestone (L in fig. 16) has been quarried below Bowden Hill from side to side, and suffers no disturbance from the vast mass of greenstone which covers it. The structure of this part of the country is shown on fig. 16. South of Lochcote the great depth of drift along the east side of the hill obscures the ground, and the limestone is not again seen at the surface for a long distance. Between Lochcote and Gormyre a thin seam of felspathic ash occurs.

Fig. 16.



The greenstone forming Bowden Hill stretches north-west into Stirlingshire and southwards beyond the village of Torphichen. It forms one of the largest undivided areas of trap in the district, and, as shown in the preceding section, is a true sheet, and not an irregular amorphous mass.

Further details of these limestones, especially of their southern prolongations, as well as of the great coal-bearing series which covers them at Bathgate, will be given in the Memoir to accompany Sheet 31. Having now traced the whole of the Carboniferous Limestone series of Linlithgowshire, from base to top, with its remarkable associated series of interbedded igneous rocks, it is necessary to return to the Edinburgh district, in order to see there a less complex development of the same series.

A. G.

CHAPTER VIII.

THE MID-LOTHIAN COAL-FIELD.

(CARBONIFEROUS LIMESTONE.)

In describing the structure of this coal-field it will be convenient to divide the subject into the three following subdivisions, which have also been distinguished on the Geological Survey Map by three different colours:—

1. The Carboniferous Limestone series, with its associated beds of marine limestone, coal, ironstone, fireclay, sandstone, and shale.
2. The Millstone Grit, consisting principally of coarse red and white sandstone and conglomerate.
3. The Coal-measures, which lie in the centre of the basin, the equivalents of the Coal-measure strata in the midland and south-western counties of England, and in Wales, and which here include two series of coal-beds, interstratified with strata of sandstone, fireclay, clay-ironstone, and shale.

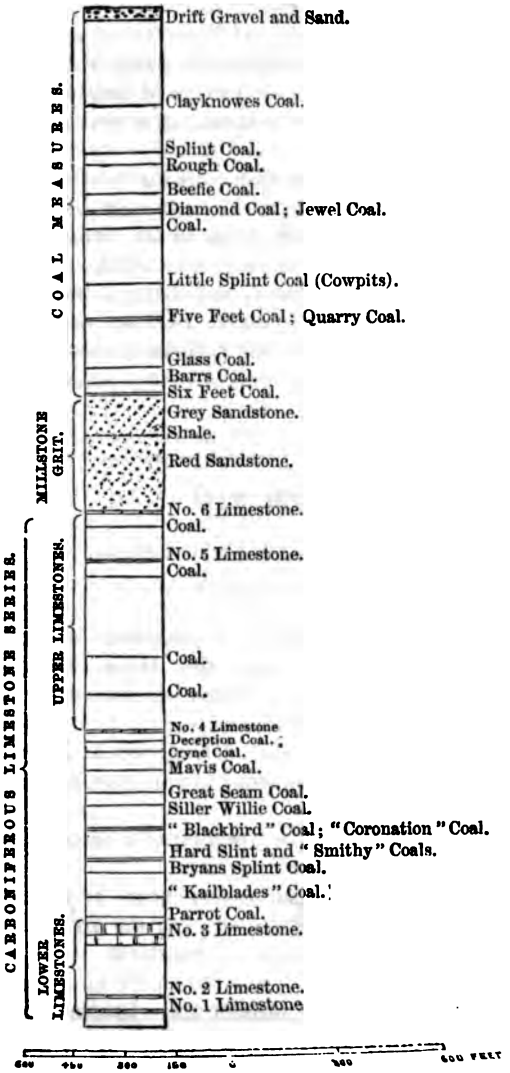
These three subdivisions constitute what is known as the Mid-Lothian Coal-field, and as developed in this district attain an average thickness of about 3,150 feet, distributed in the following proportions:—

	FT.
Carboniferous Limestone series	1,590
Millstone Grit	340
Coal-measures	1,220

They pass gradually into and are completely conformable to each other, so much so that it has been hitherto found impossible to draw any well-defined boundary between them on the map.

The general basin-shaped form of the coal-field will be seen from the horizontal sections, Plate I., and the position which the above series of rocks composing it hold to each other is shown in the vertical section, fig. 17. The former, taken

Fig. 17.—*Vertical Section of the Mid-Lothian Coal Field.*



across the northern and central parts of the district, give the different formations in their most complete development, and are on a scale of one inch to a mile; and the latter, which is framed from actual borings, gives the thickness of the Carboniferous rocks in the neighbourhood of Dalkeith, from the highest beds in the Coal-measures down to the lowest bed of marine limestone in the Carboniferous Limestone series.

1. *The Carboniferous Limestone Series.*—Of the various strata which make up this formation, the limestone beds form a very small proportion, being only six in number, and having an average thickness together of about 40 feet. The most important of these lie at the base of the series, and are generally separated into three by partings of other strata. The remaining beds are higher in the series, and are separated from the former by a considerable thickness of sandstone and shale, together with some of the principal seams of coal that are wrought in the coal-field.

By referring to the Geological Survey Map and the Index, Plate I., of which this Memoir is a description, the three lower beds of limestone will be seen forming a continuous belt on the west side of the basin at the base of the Carboniferous Limestone series. Commencing on the shore at Portobello, they strike in a south-west direction through Duddingston Mains and Niddry, to Gilmerton, at which place they bend round in a horse-shoe form by Moredun, and from thence continue through Dryden, the Bush, and Glencross Water, dipping a little to the south of east at a very high angle. Between Glencross Water and Penicuik House, a distance of nearly three miles, these limestones have never been seen or proved, on account of the great thickness of drift which obscures the whole of the underlying strata. In the grounds of Penicuik House the same limestones again appear, still inclining at a high angle to the south-east, and strike in a south-west direction through Brunston and Ninemile Burn to Newhall, at which place they cross the North Esk River, and pass into Peeblesshire, skirting round a portion of the coal-field which runs into that county. As shown on the map, the Carboniferous Limestones rise on the opposite side of the coal-field, and make their appearance at Ann's Mill and Mosshouses, dipping to the north-west at an angle of from 20° to 30°. Bending round the small promontory of the Lower Silurian rocks near Ferniehole, the limestones flatten out, and at the same time become much thicker, and the intermediate strata also become so calcareous that it has been found impracticable to draw any definite lines showing each bed separately, and from this point along the southern outcrop of the coal-field they have been massed together and mapped as if in one bed, although they are still divided by thin intervening strata of sandstone and shale, for which, as just stated, it has been found impossible to define a continuous boundary.

As seen on the map, these limestones form a belt from half a mile to 1½ miles broad, cropping out along the southern limits of the coal-field at Mount-Lothian, Fountainside, Esperston, Arniston, Middleton, and Crighton, which continues from thence eastward into Haddingtonshire.

The same limestones also rise to the surface along the ridge which forms the anticlinal curve between the Mid-Lothian and East-Lothian coal-fields, and occupy two inlying areas, one at the Roman Camp, and the other a little further to the north, between Coldwells and Cousland.

Associated with these limestones, and lying immediately under the middle one, is a bed of coal, known on the west side of the coal-field as the North Greens Seam. It varies much in thickness and quality, but is generally constant over the whole district, although it has never been wrought to any extent on the east side of the basin.

The three other beds of limestone which occur higher in the series, are not so well known as those whose general outcrop has just been described, and it has not been possible to lay them down on the map in a continuous line throughout the whole coal-field, although, from the detached places where they are seen, there can be little doubt that they are constant over the district. The two upper beds crop out on the shore at Joppa near Portobello, on the west side of the coal-field, and the third, although obscured by sand on the coast, is exposed inland at Joppa quarry. Further to the south-west they are all seen in Dryden Burn, near Loanhead. From this point to Greenlaw they are not visible, the country being thickly covered with Drift where they should appear. At Greenlaw the lowest bed is exposed in the burn at Greenlaw Mains, and in the grounds of Penicuik House the two lowest beds crop out in the North Esk River at the saw mill.

On the east side of the basin the same three limestones can be seen on the shore between Westpans and Prestonpans, and inland the two lowest have been proved in Wallyford colliery, and also at Cowden colliery and the New Mills level near Dalkeith. In the South Esk River, at Arniston, the highest bed is seen, and from this point they are not visible till we get to Penicuick, where the two highest are exposed in the North Esk at Valleyfield Mill, and about a mile further south in Black Burn. At nearly all these places they can be easily recognized from the seams of coal with which they are associated, and which have in most places been wrought.

In describing in more detail the beds of limestone, coal, and other strata which compose this series of rocks, it will be convenient to take them in the following sections, viz.:—

A. *The three lower limestones, with the North Greens coal-seam.*
B. *The beds between the third and fourth limestones.*
C. *From the fourth limestone up to the base of the Millstone Grit.*

A. *Lower Limestones and North Greens Coal.*—On the shore at *Portobello* the strata are covered by sand and Drift, and no rocks can be seen; but indications of the limestone beds were found in digging the foundations of the houses at the east end of the town, so that the position in which they are laid down in the map on the coast is only approximately true.

The first place where we have any evidence of these strata is at East Duddingston, where two beds of limestone were found during the excavations for the foundations of some buildings. According to Mr. Milne* one bed was from 2 feet to 3 feet thick, and the other about 6 feet. These were probably the two lowest beds.

The next place where they have been seen is at Niddry mill, having much about the same thickness, and from thence they continue almost in a straight line through Niddry and Edmonston to Ferniehill. Here the lowest limestone has been extensively wrought in former times, and dips to the south-east at an angle of 30°. From this point the strata make a sudden bend, and the limestone can be traced by means of the old quarries through Moredun Mains to Burdiehouse Burn, dipping a little to the south of west at an angle of from 30° to 40°. At Burdiehouse Burn the strata make another sudden turn, and strike to the south-west to Moredun mill, dipping to the south-east at an angle of 50°, and gradually curve round by the village of Stenhouse to Hynot's mill, where the limestone dips due north at 15°, forming between this place and Ferniehill a complete trough. Here, again, the lowest limestone turns suddenly, and strikes nearly due south, and its outcrop is clearly defined for nearly a mile along the range of the Gilmerton quarries. It is 10 feet thick, and of a dark blue crystalline character, surmounted by a considerable thickness of calcareous and black shale, from which the following fossils have been obtained:—*Productus longispina, P. semireticulatus, Chonetes Hardrensis, Aviculopecten arenaceus,* and another species, *Ctenodonta,* (*Nucula*) *brevirostrum,* a *Macrocheilus, Fenestella plebeia,* &c.

The second limestone and the North Greens coal, after passing Ferniehill, do not bend round and follow the same direction as the lowest bed, but continue on in the same strike, making only a slight curve between the village of Gilmerton and Moredun. A detached portion of these strata lie in a small basin by themselves within the trough formed by the lowest limestone at Moredun. The North Greens coal is here nearly 4 feet 6 inches thick, of which 1 foot 6 inches is "Parrot," and the rest, in the nomenclature of the district, a "Rough coal." The limestone which lies above is 6 feet thick, and is separated from it by 17 feet of strata consisting of sandstone and shale.

The third limestone, which has never been seen between the shore at Portobello and Gilmerton (although it is most probable it would be found close above the "Vexhim" coal), crops out immediately to the east of Gilmerton House, and was passed through in a pit which was sunk to the North Greens coal. It was here 5 feet thick, with 19 feet of calcareous shale above, and the "Vexhim" coal, which is 2 feet 2 inches thick, lies below, and is separated from it by 11 feet of black shale. The following section* gives in detail the character and thickness of the strata passed through at this pit, from the third limestone down to the North Greens coal.

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* Memoir on the Mid-Lothian Coal-field, p. 88.

Section of the Strata in the Engine Pit, near Gilmerton House.

		FT.	IN.
	Calcareous shale (limestone blaes)	19	0
	Limestone (third bed)	5	0
	Shale (blaes)	11	0
	Vexhim coal	2	2
	Shale (blaes)	4	0
	Coal	1	2
	Sandstone (freestone)	11	0
	Shale (blaes)	3	0
	Sandstone	54	6
	Shale (blaes)	2	6
	Calcareous shale (limestone blaes)	8	3
	Coal	2	0
	Micaceous sandstone (fakes)	7	6
	Shale (blaes)	1	6
	Sandstone (freestone post, and fakes)	20	6
	Shale, with ironstone balls (blaes)	18	6
	Micaceous sandstone (fakes)	2	0
	Calcareous shale (limestone blaes)	6	0
	Shale (blaes)	1	6
	Coal	1	0
	Fine Splint coal	2	0
	Sandstone (freestone and fakes)	4	0
	Shale (blaes)	28	6
	Carle	1	0
	Coal	0	9
	Shale (blaes)	0	6
	Red sandstone	146	6
	Shale (blaes)	91	3
	Shale (blaes)	57	0
	Limestone (second bed)	6	0
	Shale (blaes)	3	0
	Sandstone	1	3
	Clay	0	9
	Sandstone (freestone and fakes)	7	3
	Shale (blaes)	1	0
	Sandstone (fakes)	1	0
	Shale (blaes)	6	0
North Greens coal.	Parrot coal	1	4
	Hard band (ironstone ?)	0	6
	Fireclay	0	9
	Parott and Rough coal	3	0
	Total	545	5

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* Communicated by Mr. Marshall, Mining Engineer, Edinburgh.

From this section it appears that between the second and third limestones there are 520 feet of strata, consisting of alternations of sandstone, shale, and thin beds of coal, and that the North Greens coal lies about 26 feet under the second limestone. The lowest bed is about 90 feet below this, but the details of these strata have not been proved.

After passing Gilmerton the three limestones approximate again to each other at West Edge, on account of the uniformly high angle of inclination which the beds here assume. Between West Edge and Loanhead they are shifted forward to the south-east by three successive faults, which are all "downthrows" on the south-west; but the precise amount of the "throw" where they affect the limestones is not correctly known. Passing through Loanhead at the west end of the village, the lowest limestone crops out at the Fountain, and the North Greens coal and second and third limestones a little further east, the whole having a dip to the south-east of 40°. Between Loanhead and Bilston Burn they are again shifted by three faults, which have been proved in the coal workings; but the extent to which they affect these strata is also not known, although it is probably very trifling, for immediately beyond the three limestones are seen in the deep ravine near Dryden, crossing Bilston Burn in nearly the same line of strike. The section of the strata exposed here is exceedingly clear, for the whole of the lower limestones in succession can be seen dipping to the south-east, at an angle of 40°. The first is 10 feet thick, and very similar to the same bed at the Gilmerton quarries, and has been worked here to some extent. The North Greens coal is 4 feet 6 inches thick, and was wrought to a considerable depth in the year 1709. The second limestone lies about 20 feet above the coal, and is 6 feet thick; and according to an old section taken in the year 1694 the third bed is 300 feet above this, separated into two beds by a parting of calcareous shale, and is 10 feet thick.

These strata are not seen again till they cross Glencross Water, a distance of nearly two miles, the intervening country being much covered by Drift, and there are no natural sections to expose the rocks beneath. One of the limestones is said to crop out behind the cottages of Gowklie Moss, but which bed could not be ascertained. The third limestone has been quarried within the grounds of The Bush, where it dips to the south-east at 65°.

The section exposed in Glencross Water is not very clear, and the rocks are only laid bare for a short distance. The three limestones and North Greens coal can, however, be distinctly made out, the latter having apparently been wrought at some former period, but there are no records showing to what extent. The other strata have much the same thickness as at Bilston Burn, and the whole dip south-east at an angle of 65°.

As previously stated, the lower strata of this series between Glencross Water and Penicuick House are obscured by a very thick deposit of the Drift boulder-clay, and the position in which the three lower limestones are laid down on the map is not intended to be definite, but to show the probable line of outcrop beneath the overlying drift, and also their connexion with the same strata which are exposed in Harken Burn, the next place where they are seen in section. This has not been done entirely without data, for although none of the rocks are visible, some of the coals which lie above the limestones have been formerly worked at Greenlaw and Mauricewood. One seam especially, the Corbie Craig, has been much wrought, and its average distance above the third limestone is known; and the whole of the strata being at this point in nearly a vertical position, the thickness of the beds between them will be about the distance at which the third limestone will crop to the surface west of the Corbie Craig coal. There is only one place that helps to connect the limestones between Glencross Water and Harken Burn, near Penicuick House, where the strata are again seen. This occurs in a small burn in the grounds of Penicuick House, between the North Lodge and Carsewell. A bed of limestone is here laid bare dipping south east at an angle of 70°, and it so exactly coincides with the position in which the third bed ought to be found that I have had no hesitation in mapping it as such, although only a very small portion of it is exposed.

In Harken Burn the strata are considerably broken and contorted, which is accounted for by a fault which runs in a nearly north and south direction, and throws down the strata on the west. The second and third limestones are only exposed here, the former having increased in thickness, and being in two beds separated by shale, the latter being also a double seam, but on account of the disturbed state of the strata the thickness of neither could be ascertained with correctness. Between Harken Burn and Nine-mile Burn the whole of the beds have been proved and wrought at Brunston colliery, and also the North Greens coal, which is here 1 ft. 6 in. thick.*

After being slightly interrupted by a fault which runs north-west and south-east through Brunston colliery, these strata are next seen in Nine-mile Burn, much disturbed and contorted, the beds in some places bent over, and having a reverse dip to the north-west towards the Pentland Hills.

Section of the Lower Limestones in Nine-Mile Burn.

			FT.	IN.
1.	Black shale.			
2.	Greyish blue crystalline limestone (No. 1)		12	0
3.	Shale, with ironstone balls and sandstone		32	0
4.	Limestone		3	0
5.	Sandstone		18	0
6.	North Greens coal		2	0
7.	Yellow sandstone		12	0
8.	Limestone, crystalline, with *Encrinites*, *Spirifers*, and small *Producti*.	No. 2.	20	0
9.	Calcareous and black shale.			
10.	Limestone		8	0

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* Milne on the Mid-Lothian Coal-field, p. 86.

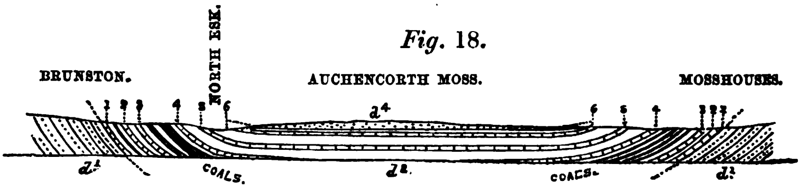
	FT.	IN.
11. Calcareous and black shale, and sandstone.		
12. Limestone	3	0
13. Sandstone	12	0
14. Limestone	4	0

It will be seen from this section that the limestones on the whole have changed considerably and become of greater thickness, and that the intermediate strata have thinned away. The vertical position, and in some places reversed dip, which the beds here assume, is due to their proximity to the great fault which runs along the east side of the Pentland Hills.

Immediately after crossing Nine-mile Burn, the limestones are thrown up and shifted slightly to the eastward by an east and west fault, the amount of "throw" of which is not known. Beyond this fault they continue through the grounds of Newhall House to the North Esk River at "Peggy's Pool," where the strata making a sudden bend, roll over, and dip towards the west, and curving sharply round on the north side of the river, re-cross the Esk in a vertical position at the foot-bridge near Amazendean, thus forming an anticlinal and synclinal axis between Habbie's Howe and the foot-bridge.

After crossing the North Esk River the limestones continue for a short distance, and are then interrupted by a large fault having a "downthrow" to the north, which shifts the strata to the east as far as Kittly Bridge in Peeblesshire. From this point, as previously stated, they skirt round a portion of the coal-field, which runs into that county as far as Magbie Hill, and next make their appearance in this Map on the opposite side of the basin, about 2 miles south-east of Penicuick at Venturefair and Mosshouses. It appears that here there are only two main beds of limestone, which are commonly believed to be the first and third beds. I am inclined to think that this opinion is so far correct, and that the second and third beds are here merged into one by the thinning out of the intermediate strata, or else that these strata become more calcareous, and that they continue so all along the southern outcrop of the coal-field. Both were formerly worked at Venturefair, but only a small portion of the second bed is visible now, and is of a dull yellow, semi-crystalline character, and dips to the north-west at an angle of 20°, forming a trough about 4 miles in width between this point and the western outcrop of the same beds at Brunston before described, as shown in the accompanying section.

Fig. 18.



Lower carboniferous strata.—d^1. Millstone grit.—d^2. Carboniferous limestone series.—1, 2, 3, 4, 5, 6. Limestone beds.

East of Venturefair, and along the southern outcrop of the Carboniferous Limestone series, it has been found impossible, as already stated, to separate the lower limestones into distinct beds on the map, on account of the much greater thickness which they here attain. It must not be supposed that the whole of that belt of blue is solid limestone, but that the whole of the lower beds are contained within it, including the intermediate strata of calcareous shale.

The place where these beds increase in thickness is where the limestones mantle on the north and east round the Lower Silurian rocks, a small portion of which project into this Sheet near Venturefair. At the same time, the limestones become much flatter, and at their upper edge contour along with the features of the ground at a distance of from 3 to 5 miles from the Lower Silurian strata of the Moorfoot Hills. They are at the present time extensively wrought at Mount Lothian and Hillhead near Cockinnie Bridge; at the latter place the section exposed in the quarry is as under:—

1. Calcareous shale, with *Encrinites*, &c.
2. Concretionary limestone bands, with shale between.
3. Hard blue crystalline limestone.
4. Band of calcareous shale.
5. Hard blue crystalline limestone.

The same bed is also wrought at the side limeworks near Fountainside, where the following section is exposed:—

	FEET.
1. Sandstone.	
2. Concretionary limestone bands.	
3. Limestone - - -	7
4. Band of calcareous shale.	
5. Limestone - - -	9

The limestone quarried at both these places is the lowest bed in the series, and is the same as the Gilmerton limestone, previously described, on the west side of the coal-field, but of much greater thickness.

The second and third beds were also formerly wrought at Fullarton, and are here nearly 30 feet thick, surmounted and separated by calcareous shale. These same beds are also exposed in the South Esk River at Yorkston, and are there separated by a thin coal with a fireclay under. This seam of coal is at present wrought at Fountainside, but I was informed it was not continuous, the two beds of limestone sometimes coming together.

In the Middleton North Burn, which flows past the farm of Esperston, the whole of the lower series of limestones are exposed, and in consequence of the low curves in which the strata are disposed, the intermediate beds have here an apparently greater thickness than is actually the case. The second and third beds on the east side of the burn are wrought at the Arniston Limeworks, and are separated by the same seam of coal which occurs at Fountainside, and which is here nearly 2 feet thick. The limestones together are about 26 feet thick.

The lowest which is seen in the burn south of Esperston is about 18 feet thick, and is worked at Middleton, and again crosses the burn at North Middleton. The following fossils have been collected here: *Productus fimbriatus*, *P. longispina*, *P. punctatus*, *P. giganteus*,* *Spirifer trigonalis*, *S. lineatus*, *Orthis resupinata*, *Bellerophon apertus*, with *Lithostrotion*, and the well known palæozoic urchin *Archæocidaris Urii* of Fleming.

Between Middleton and Arniston the strata are apparently thrown down on the west by a north and south fault which slightly alters their course, and where the lower beds are seen crossing the burn at North Middleton, the dip is very nearly due west at an angle of 10°, and continues as far as the Catcune Limeworks near Fushiebridge. The highest bed has been quarried here, but the lower strata are not exposed, being obscured by a thick deposit of Drift, till they again make their appearance in the Tyne Water at Crighton with a northerly dip. The lowest limestone was formerly worked, and is still seen in an old quarry near Crighton Church. It is a blue concretionary crystalline limestone with *Encrinites*, *Producti*, and *Corals*. The second and third beds are at present extensively wrought at the Currie Limeworks.

The Roman Camp, Fordel and Cousland Limestones.—These strata are the equivalents of the beds which have just been described, and rise to the surface along the ridge which forms the anticlinal between the Mid-Lothian and East-Lothian Coal-fields at the above-named places. They exist here in three beds, and the following section gives the thickness of each, with the intermediate strata:—

Section of the Lower Limestones at the Roman Camp.

		FT.	IN.
	Grey limestone shale - - -	3	0
	Calcareous shale with large irregular limestone nodules - - - -	31	6
No. 3.	Limestone (wrought) - - - -	5	0
	Shale - - - - - -	4	0
	Sandstone - - - - -	58	6
	Black shale - - - - -	6	6
No. 2.	Limestone - - - - -	2	0
	Shale - - - - -	2	0
	Limestone - - - - -	3	10
	Shale - - - - -	60	4
No. 1.	Limestone - - - - -	8	6
	Total - -	184	8

By referring to the Horizontal Sections, Plate I., the manner will be seen in which these strata rise from beneath the Mid-Lothian Coal-field on the west, and then roll over and dip to the east.

At the Roman Camp, on the west side of the anticlinal, the second and third beds (which are here mapped as one) rise to the surface from beneath the lowest coal at New-battle Colliery, and gradually bend over at the summit of the hill and dip east. On the south end these beds are suddenly truncated by a fault having a downthrow to the south, and on the north gradually mantle round the hill to Edgehead, where the strata are again dislocated by a north-east and south-west fault throwing them down on the south-east. The lowest bed crops out at D'Arcy, and curves round in a semicircle, the south-east portion being thrown down by the same fault which affects the other beds at Edgehead. It was formerly extensively wrought here, and contains the following fossils:—*Encrinite* stems and *Fenestella; Productus semireticulatus; P. punctatus; Rhynchonella pleurodon; Spirifer trigonalis; Solenomya; Orthoceras (Cycloceras) annulare*, Flem.; *Nautilus* (like *N. ingens*), and *N. sulcatus*, Phil.

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* *P. giganteus* is rare in these lower limestones.

B. *The Beds between No. 3 and No. 4 Limestones.**—The strata included within this section of the Carboniferous Limestone series are most important from the number and thickness of the coal seams with which they are associated. Where most completely developed, these contain not less than 26 beds of coal above 1 foot thick. This occurs, however, only in the northern and central parts of the coal-field in the neighbourhood of Dalkeith, Newbattle, Duddingston, Niddry, Gilmerton, Loanhead, and Dryden. Along the southern and south-west outcrop most of these coals have thinned away, and are not of sufficient thickness to be workable, although there is no doubt that the thin seams which remain are the representatives of those which are so completely developed in the northern part of the coal-field.

By referring to the Vertical Section, fig. 17, these strata will be seen to occupy an intermediate position between the three lower limestones, and the other three which occur higher in the series. On the west side of the coal-field they crop out on the coast at Joppa near Portobello, and strike inland through Duddingston, Niddry, Drum, Gilmerton, Loanhead, and Dryden. At all these places they are locally known as the "Edge Seams," on account of the high angle and sometimes vertical position in which the beds are tilted. South of Dryden they have been worked at Greenlaw, and are at present mined at Brunston, between Penicuick and Carlops, although considerably altered in thickness.

On the east side of the coal-field the same coals crop out on the coast at Prestonpans, and inland at Wallyford, Carberry, Cowden, Newbattle, and Arniston; and bending over the anticlinal ridge between the Roman Camp and the shore at Prestonpans form the East-Lothian Coal-field, mapped in the adjoining Sheet.

Joppa, Duddingston, Niddry, Drum, and Edmonston.—On the shore at Joppa the strata are entirely obscured by the sand between low and high water mark, but about a quarter of a mile inland the higher beds connected with these strata are exposed in Joppa quarry, having a dip to the east of 55°. The whole of the coals, however, of this series have been proved in the mining operations which wer formerly carried on at Duddingston, and as they have a very uniform thickness between the shore at Joppa and Drum, near Gilmerton, the following section, giving the local names of the coal-seams and the thickness of the intermediate strata between them, will apply for the whole distance. The section is given in descending order.

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* *See* Vertical Section, p. 73, and Horizontal Sections, Plate I.

Section of the "Edge" Coals at Duddingston.

	FT.	IN.		FT.	IN.
			Brought forward -	417	6
Flex coal - - -	4	0	Intermediate strata -	30	0
Intermediate strata -	30	0	Little Splint - -	3	0
Laverock coal - -	3	0	Intermediate strata -	60	0
Intermediate strata -	24	0	Big Splint - - -	4	0
Great Seam - -	8	0	Intermediate strata -	60	0
Intermediate strata -	36	0	Corbie Craig - -	5	0
Stairhead - - -	4	6	Intermediate strata -	150	0
Intermediate strata -	60	0	Stony coal - - -	5	0
Gillespie - - -	4	6	Intermediate strata -	78	0
Intermediate strata -	142	0	Carleton - - -	5	6
Little Gillespie - -	3	0	Intermediate strata -	54	0
Intermediate strata -	30	0	Rough coal - - -	3	9
Black chapel - -	5	6	Intermediate strata -	30	0
Intermediate strata -	60	0	Blue coal - - -	3	9
Stinkie - - -	3	0			
Carried forward -	417	6	Total thickness -	909	6

The above section, as will be seen, is of a very general nature, and as there are no mines now in operation at Duddingston I have not been able to give a more detailed account. I believe, however, that this section may be relied upon as being correct so far as it gives the principal coal-seams and the thickness of the strata which separate them.

At Niddry Burn, about a mile from the shore at Joppa, these coals are all intersected by a greenstone dyke, which crosses the strata nearly at right angles, but does not displace them on either side. South of this dyke the coals continue uninterruptedly almost in a straight line on account of the high angle at which they dip between Niddry House and Cloverfoot to Edmonston. Immediately north of Edmonston they are intersected by a slip fault, which is a downthrow on the south, and shifts the strata slightly to the west. This fault was proved in the coal workings, but the amount of "throw" is not known.

South of Edmonston, the high angle at which the strata dip increases, and at Drum they are in a perfectly perpendicular position. This may be seen in some old quarries at Drumbank, where the same strata and some of the same coals which are exposed in Joppa quarry are again visible. The coals here exposed are the "Flex," "Rumbold," and "Laverock" seams, which lie immediately above the Great Seam. The sandstone that has been quarried is the bed which forms the roof of the Great Seam, which is generally constant and easily recognized by the miners throughout this part of the coal-field. At the south end of this quarry the strata are displaced by a small fault, throwing them down on the south side; and further south, between Drum and Gilmerton, another fault intersects the coals, also throwing them down on the south, and shifting the great seams about five chains to the west.

Gilmerton, Loanhead, and Dryden.—At Gilmerton and Dryden the "Edge" coals were formerly extensively wrought, and more recently at Loanhead. Unfortunately, the sections of the strata which have been preserved are, as in the Duddingston district, given only in a general way, with the thickness of the most important seams of coal, but no details of the intervening strata. The following section, taken from an old document in the possession of Sir David Baird, gives the coals and the thickness of the strata which separate them at Gilmerton.

Section of the Edge Coals and intermediate Strata at Gilmerton.

	FT.	IN.	FT.	IN.
Flex coal	4	0	–	
Intermediate strata	-	-	60	0
Rumbold coal	2	0	–	
Intermediate strata	-	-	6	0
Laverock coal	3	0	–	
Intermediate strata	-	-	36	0
Great Seam coal	10	0	–	
Intermediate strata	-	-	18	0
Stairhead coal	3	6	–	
Intermediate strata	-	-	66	0
Gillespie coal	3	6	–	
Intermediate strata	-	-	60	0
Black Chapel coal	7	0	–	
Intermediate strata	-	-	9	0
Perpetual coal	2	9	–	
Intermediate strata	-	-	24	9
Kittle Purse coal	2	2	–	
Intermediate strata	-	-	120	0
Stinkie coal	4	0	–	
Intermediate strata	-	-	24	0
Rough coal	4	9	–	
Intermediate strata	-	-	114	0
Parrot coal	-	-	–	
Intermediate strata	-	-	–	
Coal	3	9	–	
Intermediate strata	-	-	60	0
Corbie Craig coal (with parting)	8	0	–	
Intermediate strata	-	-	48	0
Peacocktail coal	4	0	–	
Intermediate strata	-	-	54	0
Carleton	5	6	–	
Intermediate strata	-	-	84	0
Blue coal	7	0	–	

It will be seen from this section that many of the seams of coal have altered in thickness, while at the same time other coals have apparently appeared. From the very unsatisfactory way in which the old sections have been taken, it is not at all improbable that the additional coals which are given in this section are also in the Duddingston and Edmonston districts, but there only represented by thin and unimportant seams. There is, however, no difficulty in making out the most important coals, such as the Great Seam, Black Chapel, and Corbie Craig, which have generally been wrought to a greater extent than the other beds, and are therefore better known, and found to occupy the same position in the series.

South of the fault which was last mentioned, as throwing down the strata on the south side at Drum, the coals from the "Black Chapel" upwards, given in the preceding section, continue in nearly a straight line, and dip to the east, at angles varying from 65° to 75°, while the lower seams bend slightly round by Gilmerton, the dip of the strata being much less at an angle of 40°. Between Gilmerton and Gilmerton House the whole of the coals are interrupted by a fault, which runs in a north-west and south-east direction, and nearly parallel to the last one. It throws the higher coals and their associated strata down 45 fathoms on the north side, but dies away gradually to the crop of the lower seams, and in the Gilmerton limestone quarries the "throw" is only a few feet.

Between Gilmerton and Loanhead the coals are intersected by a series of slip faults, the first of which runs in an east and west direction by Laverock Hall, and another nearly at right angles to this one between that place and West Edge. Both of these are small, and displace the strata very slightly, the former throwing them down on the south, and the latter on the east side. Immediately south of West Edge a third fault throws down the coals considerably on the north, branching into two towards the higher beds, and at Edgefield two parallel ones cross the strata in a north-west and south-east direction, both throwing down the coals on the same side, the first 55 and the other 60 fathoms.

At Loanhead the following section gives the principal coals and the thickness of the strata between them, but, as in the former sections of Gilmerton and Duddingston, no details of the nature of the rocks have been taken.

Section of the "Edge" Coals at Loanhead.

	FT.	IN.	FT.	IN.
Flex coal - - -	5	0	–	
Intermediate strata - - -	-	-	60	0
Parrot coal - -	3	0	–	
Intermediate strata - -	-	-	23	0
Great Seam - - -	8	0	–	
Intermediate strata - -	-	-	23	0
Stairhead coal - -	3	4	–	
Intermediate strata - -	-	-	63	0
Charlies coal - -	2	0	–	

	FT.	IN.	FT.	IN.
Intermediate strata	-	-	20	0
Moffat coal	2	0	–	
Intermediate strata	-	-	10	0
Gillespie coal	3	4	–	
Intermediate strata	-	-	40	0
Coal ⎫	5	10	–	
Parting ⎬ " Black Chapel "	-	-	7	4
Coal ⎭	2	2	–	
Intermediate strata	-	-	32	0
Kittle Purse	3	0	–	
Intermediate strata	-	-	67	0
Stinkie coal	5	0	–	
Intermediate strata	-	-	60	0
Rough coal	3	0	–	
Intermediate strata	-	-	20	0
Glass coal	3	6	–	
Intermediate strata	-	-	30	0
Brown's coal	2	6	–	
Intermediate strata	-	-	56	0
Stony coal	5	0	–	
Intermediate strata	-	-	10	0
Hope's coal	2	0	–	
Intermediate strata	-	-	20	8
Beatties coal	3	0	–	
Intermediate strata	-	-	20	0
Corbie Craig	8	0	–	
Intermediate strata	-	-	100	0
Little Splint coal	4	0	–	
Intermediate strata	-	-	30	0
South coal	5	0	–	
Intermediate strata	-	-	40	0
North coal	4	6	–	
Intermediate strata	-	-	300	0
Limestone (No. 3.)				

By comparing this section with that of Gilmerton, given previously, it will be seen that here there are many more thin coals, especially between the Corbie Craig and Black Chapel, which are not mentioned as existing in that section, but it will be observed that the thickness of the strata taken altogether between these two principal coals is nearly equal, which makes it extremely probable that some of the thin seams have been omitted from the Gilmerton section, because they were not of sufficient thickness to be of any value.

Between Loanhead and Dryden three faults have been proved in working the coals. The first which runs parallel with the two mentioned previously at Edgefield, crosses the strata near Burghlee, and throws them down on the north side 40 fathoms. The other two run in an east and west direction between Burghlee and Bilston Burn, and are downthrows on the south side, but do not displace the strata to any great extent.

At Bilston Burn, near Dryden, the strata associated with these coals are laid bare, but it is now so overgrown with underwood that it is not practicable to make a correct section. Most of the seams have, however, been wrought formerly, and the following section* gives the thickness of the principal coals and intermediate strata as they stand in the mines of Burghlee.

Section of the "Edge" Coals at Dryden.

		FT.	IN.	FT.	IN.
Flex coal		5	0	–	
Metals	[Intermediate strata]			84	9
Parrot coal		4	0	–	
Metals	Do.			36	0
Great Seam		14	0	–	
Metals	Do.			50	3
Stairhead		3	1	–	
Metals	Do.			87	8
Gillespie		3	3	–	
Metals	Do.			96	0
Black Chapel		4	8	–	
Metal	Do.			24	0
Thin coal		1	10	–	
Metal	Do.			48	0
Splint coal		2	9	–	
Metal	Do.			66	0
Stinkie coal		4	6	–	
Metal	Do.			36	0
Thin coal		1	1	–	
Metal	Do.			54	0
Glass coal		3	0	–	
Metal	Do.			18	0
Parrot coal		2	0	–	
Metal	Do.			156	0
Thin coal		1	0	–	
Metal	Do.			24	0
Stony coal		4	0	–	
Metal	Do.			54	9
Thin coal		0	9	–	
Metal	Do.			33	9
Corbie Craig coal		8	3	–	
Metal	Do.			6	0
Splint coal		3	0	–	
Metal	Do.			168	0
Little Splint coal		1	6	–	
Metal	Do.			42	0
Little coal		1	3	–	
Metal	Do.			9	0
South coal		5	3	–	
Metal	Do.			36	0
Little Splint coal		1	6	–	
Metal	Do.			9	0
North coal		3	0	–	
Metal	Do.			276	0
Limestone (No. 3.)					

The principal seams of coal given in the above section have been worked for a considerable distance to the south-west of

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* *This section* was measured in 1694, and was copied from one in the possession of *Mr. Geddes, Mining* Engineer, Edinburgh.

Dryden, but I was not able to obtain any records of the old workings. There is no doubt, however, that most of the coals deteriorate in value, and that the intermediate strata undergo a great alteration in thickness somewhere between Dryden and Greenlaw, a distance of about 3 miles; but as there are no sections of the rocks exposed no information can be obtained except by boring. It is said that the Corbie Craig has been worked the whole distance in former times, and the old pit at Gowklie Moss was on that seam.

Greenlaw, Penicuick, and Brunston.—At Greenlaw these coals were wrought as late as the year 1840, and the following section gives the number and thickness of the seams and intermediate strata as they occur there in descending order.

Section of the "Edge" Coals proved at Greenlaw.

	FT.	IN.
Coal - - - - -	2	6
Intermediate strata -	21	0
Coal - - - - -	2	0
Intermediate strata -	39	0
Coal - - - - -	1	6
Intermediate strata -	18	6
Coal - - - - -	2	3
Intermediate strata -	46	6
Coal - - - - -	2	2
Intermediate strata -	56	0
Black-Band ironstone -	1	2
Intermediate strata -	4	4
Coal (Great Seam) -	4	0
Intermediate strata -	42	0
Coal - - - - -	3	0
Parting (thickness not given)		
Coal - - - - -	1	4
Intermediate strata -	14	6
Coal (Black Chapel) -	2	6
Intermediate strata -	30	0
Coal - - - - -	2	5
Intermediate strata -	14	6
Coal - - - - -	2	6
Strata (thickness not known)		
Corbie Craig coal - -	5	8

By comparing this section with those of Dryden and Loanhead, it will be seen that the principal coals—the Great Seam, Black Chapel, and Corbie Craig—have become much thinner, and that some of the less important ones have thinned away altogether. There is also mentioned in this section a bed of the Black-band ironstone, 1 foot 2 inches thick, occurring 4 feet above the Great Seam, which is not known to exist in the other districts just described.

Between Greenlaw and Brunston the Corbie Craig coal is the most important bed, and is said to have been wrought at intervals nearly the whole distance between these places. In the plantations at Mauricewood and Bellwood, near Greenlaw, there are numerous old pits, all said to be on this seam, but to what extent it has been worked is not known. In the grounds of Penicuick House many of the coals besides the Corbie Craig are seen, and in the burn, near Penicuick Tower, an old mine stands open, which is said to be driven to the Corbie Craig. The two thin coals which cross the burn here are the Flex and Rumbold seams, recognized by the bed of limestone which always occurs above them. The same coals, also, can be seen crossing Harken Burn near Brunston, together with the Black Chapel, Glass Beattie, Corbie Craig, and North and South coals. They dip t the south-east at a very high angle, being sometimes also in vertical position. They are intersected here by the same fault which is seen to displace the limestone beds, and shifts the strata on the west side further to the south.

At Brunston colliery the following detailed section of the coals and intervening strata has been measured.*

Section of the "Edge" Coals at Brunston Colliery.

	FT.	IN.
Limestone (No. 4.)	4	0
Sandstone	16	0
Flex coal	2	10
White fireclay	13	2
Coal (Rumbolds)	4	11
Sandstone and fireclay	2	3
Coal (Laverock)	0	10
Sandstone	33	11
Coal	0	11
Sandstone	24	8
Coal (Great Seam)	1	0
Fireclay and ironstone balls	5	3
Coal (Stairhead)	1	11
Fireclay and ironstone balls	3	3
Coal (Gillespie)	1	8
Indurated clay	8	7
Coal mixed with stone	0	9
Sandstone	22	6
Fireclay	1	1
Sandstone	74	3
Shale (Blaes)	12	10
Splint coal	1	0
Shale (Blaes)	4	0
Coal (Glass)	2	0
Indurated clay	2	2
Stony coal	1	3
Coarse grey sandstone	18	0
Coal (Hope's)	0	8
Fireclay, with ironstone balls	6	0
Coal (Beattie)	1	11
Sandstone and shale	30	0
Fine white sandstone	34	6
Coal } (Corbie Craig)	3	0
Fireclay } (Corbie Craig)	1	3
Coal } (Corbie Craig)	2	9
Total	364	10

By comparing this section with that of Dryden it will be seen how very greatly the beds have diminished, the total thickness of coal there being 77 feet 8 inches, whereas here the same seams are only 27 feet 5 inches.

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* *Given me by Mr. J. Lawson, Manager of the Colliery.*

A large fault runs through Brunston colliery 50 fathoms wide, and filled with broken rock. Its direction is north-west and south-east, at right angles to the strike of the strata, and throws down on the north-east side. I think it is not at all improbable that this may be really two faults, and that the rocks have been broken up between them. Two other faults interrupt the coals between Brunston and Nine-mile Burn, both throwing the strata down on the north-east side. At the latter place the lower seams of coal are seen crossing the burn at a high angle, but the Great seam and those above it crop out near Marfield, and cross the North Esk River there, the dip of the strata becoming much flatter. The Corbie Craig has formerly been wrought all through the estate of Newhall, and crosses the North Esk below Newhall House. By referring to the section, fig. 18, these coals are shown to extend under Auchencorth Moss, and the Beattie and Corbie Craig seams to crop out on the opposite side of the basin near Mosshouses, where they were formerly worked by means of a "day level" from Lead Burn, the strata here dipping to the W.N.W. at 30°.

I have already stated that these coal-seams along the south outcrop of the coal-field are so thin that they can scarcely be recognized, and as they are not worked now, and have only been so to a limited extent formerly, very little information could be obtained. Two thin seams of coal are seen in an old quarry about a quarter of a mile east of White Hill tileworks, which belong to this series, but cannot be identified. In Fullarton Water, immediately below Fullarton, two other thin coals are exposed, and as they lie close above the limestone, these may possibly represent the Corbie Craig or North and South seams. In the South Esk River, between the limestone at Yorkston and the village of Temple, an ascending section of the rocks is exposed, and eight thin seams of coal can be made out, which are no doubt the representatives of those described along the west side of the coal-field. They vary here from 6 inches to 2 feet thick, but none of them can be individually identified, although it is said that the three which are seen in the cliff opposite Temple Church are the Great Seam and others in connexion with it. This is not at all improbable, as the strata here are high up in the series, and in the right position for these coals. At the saw-mill at Arniston a coal crops out, and another lower down in the series at Castleton. The former has been traced eastward through the woods of Arniston to Fushiebridge, and is probably the representative of the Corbie Craig seam. It is said to be a "rough coal," and was wrought to some extent formerly.

Arniston, Newbattle, and Cowden Collieries.—The coals connected with this series have been long and extensively wrought at these collieries, which are situated on the east side of the coal-field. The following section of the coals and intermediate strata, as they have been proved at Cowden, show the thickness of each seam.

Section of the Strata at Cowden Colliery, near Dalkeith.

	FT.	IN.
Limestone (No. 4)	4	8
Sandstone and shale	29	4
Coal (the Deception)	2	2
Sandstone	30	6
Coal (Cryne)	2	6
Sandstone	24	6
Shale	4	8
Sandstone	24	4
Coal (Mavis)	2	8
Sandstone	62	2
Coal (Great Seam)	8	0
Sandstone	7	0
Coal (the Diamond)	2	7
Sandstone and shale	15	2
Coarse blackband ironstone	0	5
Coal	1	10
Shale with bands	14	0
Coal (the Siller Willie)	6	0
Sandstone	8	0
Coal	0	6
Sandstone bands	6	6
Coal	1	0
Shale	1	4
Coal	0	6
Sandstone bands	22	0
Coal	0	9
Shale	6	8
Ironstone in balls	0	3
Coal	0	3
Shale	1	0
Coal	2	1
Shale	4	2
Coal	1	5
Sandstone and shale	13	3
Coal (the Blackbird)	3	11
Sandstone	6	6
Coal (the Coronation)	3	10
Carried forward	326	5
Brought forward	326	5
Sandstone and shale	51	6
Shale and ironstone balls	15	0
Coal (the Hard Splint)	3	3
Shale and ironstone balls	6	5
Coal (the Smithy)	2	9
Shale and sandstone	17	4
Fireclay and ironstone	4	1
Sandstone and bands	11	11
Coal (the Bryant's Splint)	5	8
Sandstone bands	16	0
Coal	0	6
Sandstone and shale	21	11
Coal (Aleck's)	2	7
Sandstone	10	8
Coal	1	1
Bands (sandstone)	12	2
Coal	2	6
Shale	1	5
Coal	0	11
Shale	4	0
Ironstone (Clayband)	0	3
Coal (Kailblades)	1	3
Sandstone	2	1
Coal (Little Splint)	2	1
Sandstone and shale	56	0
Coal	1	0
Shale	21	0
Ivonstone	0	9
Coal	2	1
Sandstone	4	5
Coal	1	7
Sandstone and shale	11	3
Coal (the Parrot)	3	0
Fire clay	1	0
Sandstone and shale	52	3
Limestone (No. 3)		
Total	678	1

This section will apply to the Newbattle and Arniston collieries; for although some of the minor seams and the intermediate strata differ, the principal beds are more regular and can be easily recognized. These are the Great Seam, Diamond, Siller Willie, Blackbird, Coronation, Bryan's Splint, Kailblades, and Parrot coals. By referring to the Geological Survey Map, and the sections, Plate I., these seams will be seen rising from beneath the coal basin on the east, and cropping out along the west side of the Roman Camp ridge, the Great Seam, and Diamond coals, with the strata above them, terminating on the south at a large fault near Gorebridge, which throws the strata down on the north-west 40 fathoms, while the lower coals, including the Bryan's Splint, Kailblades, and Parrot seams, curve round the south end of the anticlinal, and dip towards the south-east. The fault at Gorebridge was proved in the Vogrie colliery there, which was 10 fathoms to the Great Seam and 50 fathoms to the Bryan's Splint, the lower strata on the south-east side of the fault being brought against the higher, for the same Splint coal was proved to be only 6 fathoms deep in a bore about 500 yards to the south-east of the colliery, and dipping at a low angle to the north-west.

The outcrop of the Great Seam north of Gorebridge continues without any interruption of importance, by Stobhill Church, till it is intersected by two large faults at Arniston colliery, which throw down all the strata between them. Both run parallel to one another, in a nearly east and west direction, the first throwing the coals down 40 fathoms on the north and the second 30 fathoms on the south, in the higher part of the series, but become much less towards the crop of the lower seams. At the south end of the Roman Camp ridge the former truncates the limestones; but it is evidently very small here, for on the south side of it the same limestone has been proved to be only a short distance beneath the surface.

The coals generally at Arniston colliery are thinner than at Cowden near Dalkeith, as are also the intermediate strata, the Great Seam being only 7 feet thick, the Diamond 2 feet 6 inches, Siller Willie 4 feet 5 inches, Bryan's Splint 5 feet 6 inches, and Parrot 2 feet 10 inches; the latter lying 38 feet 8 inches above the third limestone.

North of the last fault mentioned at Arniston colliery, the whole of the coals continue for rather more than a mile, through Newbattle colliery, without meeting with any interruption, the outcrop of the Great Seam passing by Red Row and Lingerwood to Bryans, and the coals below cropping out between it and the Roman Camp limestones. At Bryan's they are all thrown down on the north side 14 fathoms by an east and west fault, and about a quarter of a mile beyond by another, running parallel to the last, but throwing the strata down on the south side, and a third, which intersects the Great Seam north of East Houses, also throws them down on the same side. These three faults have all been proved in the workings of the Newbattle colliery, but the number of fathoms which the two last throw down the strata is not correctly known. They all, however, become less towards the crop of the lower seams.

At Cowden the beds, from the "Deception" down to the "Coronation" coal, continue at a high angle through Capielaw and near West Cowden to the large fault on the south side of Cowden Cleuch; but the lower seams, from the Bryan's Splint down to the Parrot coal, bend round by Langlaw, Whitehall, Coldhame, and Fuffet, and follow the contour of the limestones of the Roman Camp ridge, the dip of these beds being much flatter.

Four faults interrupt the upper series of coals at Cowden: one on the south side of West Cowden, which is 15 fathoms "downthrow" on the north, and another on the north of the same place, which throws down the strata on the opposite side 7 fathoms. The next is near Cowden Cleuch, and is said to be a continuation of the large fault which was proved in the Coal-measures at Sheriffhall to throw the coals down on the north 84 fathoms; but it is certainly nothing like that amount here, and probably becomes much less toward the crop of the lower seams.

Carberry, Wallyford, and Prestongrange.—On the north side of the last fault just mentioned, very little information can be obtained concerning these strata till we reach Carberry; but the outcrop of the Great Seam as shown on the map, passing between Smeaton Shaw and the limestone of Chalkieside, is very nearly correct. Some of the lower seams have also been proved, but the strata are very much disturbed, and the outcrops of the coals have not been correctly ascertained.

Through Prestongrange, Wallyford, and Carberry, the Great Seam has been formerly wrought by means of a "day level" from the sea at Prestongrange, and its outcrop, as shown on the Geological Survey Map, can be distinctly traced, by means of the subsidence of the surface into the old workings, which were carried as far as the most northern of the three faults which are laid down on the Map between Carberry House and Carberry Old Mains, and by this level the coal is said to have been wrought out to the depth of 23½ fathoms.* On the south side of this fault, in the direction of Carberry House, the Great Seam has been worked by "open cuts" from the surface. Two other coals are mentioned as being beneath the Great Seam, and which have also been worked at Carberry, the first being a rough coal, 5 feet thick, and the second a splint coal, 3 feet 6 inches thick. There are indications on the surface of the ground through Carberry Park of these coals having been wrought formerly, and on the south they suddenly terminate, which I think must be due to a large fault which runs near Carberry House, and which I believe to be an extension of a slip which was proved in the Cowpits seams of the Coal-measures, and is said to be there 16 fathoms "downthrow" on the south, but is probably not so much at Carberry. The dip of the coals at Carberry is to the west at an angle of 25°.

At Wallyford, where the Great Seam has been recently opened up and is at present being wrought, the following section of the strata from the fourth bed of limestone down to a Splint coal which lies below the Great Seam, has been proved.†

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* The information of the Carberry coals I obtained principally from a report made in 1826, by Mr. Maclaren, Mining Engineer.

† *Communicated* by Mr. Williamson, Mining Engineer, Edinburgh.

Section of the Strata at Wallyford Colliery.

	FT.	IN.
Limestone (No. 4)	1	6
Sandstone bands and shale	29	11
Coal (Deception)	1	3
Sandstone and shale	11	1
Coal	0	9
Sandstone and bands	9	4
Coal (Cryne)	2	6
Sandstone bands and shale	32	5
Coal (Mavis)	1	0
Fireclay	1	0
Sandstone and shale	4	1
Soft Coal	0	9
Fireclay	1	9
Sandstone, shale	27	6
Coal	1	7
Shale and sandstone	2	10½
Coal	2	2
Fireclay and shale	1	3
Sandstone and shale	3	5
Coaly Ironstone	0	5
Clean do.	0	3
Sandstone and shale	6	0
Coal (Great Seam)	10	10
Fireclay and shale	1	0
Intermediate strata	31	2½
Carried forward	185	10
Brought forward	185	10
Sandstone and shale	11	6
Parrot Coal	0	8½
Shale and sandstone	8	2½
Shale	1	9
Clayband ironstone	0	2¾
Shale	4	2¼
Ironstone	0	1½
Shale and sandstone	8	4
Parrot Coal	0	8
Coal daugh	0	5
Coal	0	2½
Shale and sandstone	24	11
Shale and inch bands of ironstone	39	0
Sandstone and shale	17	3½
Coal	0	1
Ironstone	0	2
Coal daugh	0	1
Sandstone	0	5
Coal daugh	1	9
Sandstone and shale	41	5½
Blaes ribbed with *coal*	1	5
Coal (Splint)	4	6
Fakes and fireclay	1	3
Total	354	6

The strata below the Great Seam, as shown in this section, differ considerably from those of Cowden colliery in the following particulars. The "Diamond," which there lies 7 feet and at Arniston 18 feet 4 inches beneath the "Great Seam," is here merged into that coal and forms one thick seam, the strata between them having thinned away. Below the "Diamond," in the Cowden section, the first thick coal is the "Siller Willie," which apparently does not exist here, for the "Splint Coal" is too low down in the series, and is probably the equivalent of the "Blackbird" or "Coronation" seams. It will also be seen that above the "Great Seam" there is a bed of "Blackband" ironstone, not known to exist at the collieries of Cowden, Newbattle, and Arniston, which is here in the same position as a similar bed which has been already mentioned as lying above the same coal on the west side of the district at Greenlaw.

At Prestongrange the same coals have been proved as at Wallyford, together with others which lie below the Splint coal in that colliery, and which represent some of those given in the section of the Cowden strata. These are wrought at Dolphingston colliery, but the precise outcrop of the beds I could not obtain. Mr. Milne Home, in his Memoir on this coal-field, gives nine coals as having been proved below the "Great Seam," in two bores which were put down in Panwoodlees, south of Prestongrange, and the lower limestone beds are said to have been reached at a depth of 150 feet, in a bore 500 yards south-east of Dolphingston colliery. These, as well as some of the lower coals, do not rise to the surface, but mantle over the ridge at Falside, which is a prolongation of the Roman Camp anticlinal, and on the other side dip towards the east, and form the East Lothian coal-field.

The higher portion of these strata between Wallyford and the sea at Prestonpans, a shown by the outcrop of the "Great Seam," are interrupted by four considerable faults, and by a greenstone "dyke" which runs out to sea on the west, at Oxcraigs, and to the east traverses the East-Lothian coal-field. Of the former, the two first run parallel to each other north of Wallyford House, and are believed to be the same as those proved in the Coal-measures at Pinkie, where they were ascertained to throw down the strata, the first 6 fathoms on the north and the second 5 fathoms on the south side. The amount of "throw" at Wallyford is not known, but for both faults it is probably much less.

The two other faults have been proved at Dolphingston colliery and Prestongrange. The one at the former place crosses the strata in a north-west and south-east direction, and is a downthrow of 15 fathoms on the south-west side; and the other having an east and west bearing, throwing down the strata 30 fathoms on the north. The coals are not shifted in the line of the greenstone "dyke," which was proved at Preston colliery, where one of the seams was wrought up to it on the north side, and a mine being driven through it, the same coal was found on the opposite side at the same level.

I have already stated that the coals of the Carboniferous Limestone series, after rising to the surface on the west side of the Roman Camp ridge, bend over and dip in the opposite direction, forming the East-Lothian coal-field, as shown in the sections, Plate 1. There are only two places in this sheet where the coals are at present wrought on this easterly dip, viz., at the Roman Camp and Edgehead, at both of which the same seam is worked. This is the "Parrot" coal, the lowest given in the Cowden section, and which lies about 36 feet above the lower limestones, and has been extensively wrought at the Arniston and Newbattle collieries. By referring to the Geological Survey Map, this coal, together with the "Kailblades" and "Bryans Splint" which lie above it, will be seen curving round the truncated termination of the Roman Camp limestones on the south at Hillhead, and cropping along the east side of the ridge to Edgehead, with an easterly dip towards the large fault which traverses the low ground between the Camp and Vogrie. It is also said that some of the higher seams lie in this hollow between Blinkbonny and Southside, but I could never get any definite information as to which coals they were, as none of them are at present wrought.* The following is a section of the strata at Edgehead, and gives the thickness of the "Kailblades" and "Parrot" seams on the east side of the anticlinal.

Section of the Strata at Edgehead.

		FT.	IN.
	Surface	21	0
	Sandstone	20	0
	Coal	0	3
	Sandstone and shale	2	0
	Coal	0	3
	Fireclay	3	11
	Shale	3	9
	Coal	1	2
	Fireclay	1	2
	Sandstone and shale	10	6
	Coal	0	7
	Sandstone and shale	10	8
"Kailblades"	*Coal*	1	6
	Sandstone	2	11
	Coal	1	1
	Shale and sandstone	3	2
	Coal	1	10
	Sandstone and shale	78	1
	"Parrot" coal	0	10
	Rough do.	1	2
	Total	165	10

It will be seen by comparing this section with the same strata at Cowden, that the coals on this side of the Roman Camp ridge alter considerably and become much thinner.

The large fault which traverses the low ground between the Roman Camp and Vogrie, was proved in working the coal at Sauchanside, where it throws the strata up on the south-east side 18 fathoms. I believe that this is a prolongation of the same slip found at Vogrie colliery near Gorebridge, and which, as previously stated, throws the coals up on the south-east 40 fathoms at that point.

On the south-east side of this fault the strata have a contrary dip, and incline at a low angle to the north-west towards the fault, and the same coals that are given in the Edgehead section again rise to the surface in succession, and below them the lower limestones crop out in the valley of the Tyne river at Vogrie, as shown in Section No. 2, Plate I., forming the south-eastern limit of the coal-field. A descending section of these strata is exposed both in Vogrie Burn and Dewar Burn, at both of which places the coals have been wrought, although much deteriorated in thickness, as shown by the following section of a bore put down near Harvieston, on the south-east side of the fault near Vogrie colliery at Gorebridge.

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* I was, however, informed by Mr. Gibson, Manager of the Newbattle Collieries *that the "Great Seam" had been proved here.*

Section of the Strata at Harvieston.[*]

		FT.	IN.	FT.	IN.
	Surface	6	6	6	6
	Fireclay	0	6	7	0
	Sandstone and shale	5	5	12	5
	Soft Coal	0	7	13	0
	Sandstone and shale	8	5	21	5
	Coal (impure)	0	4	21	9
	Sandstone	10	5	32	2
	Splint Coal (waste)	3	0	35	2
	Sandstone and shale	26	5	61	7
	Coal	1	3	62	10
	Sandstone and shale	24	9	87	7
"Kailblades"	*Coal*	1	4	88	11
	Fireclay	0	4	89	3
	Coal	1	7	90	10
	Fireclay	1	5	92	3
	Coal	1	8	93	11
	Sandstone and shale	91	6	185	5
	Parrot Coal	0	4	185	9
	Sandstone and shale	31	7	217	4
No. 3.	*Limestone*	0	10	218	2
	Parting	0	2	218	4
	Limestone	2	0	220	4

The same coals which are found at Edgehead, are also known along the eastern side of the limestones at Fordel and Cousland, but none of them have been wrought for some time. At the former place two seams have been seen, but their outcrop is not sufficiently ascertained to be laid down on the map, neither is it possible to identify them with any individual seam, although there is no doubt that they belong to this series, and are not very far above the lower limestones. They both dip to the east and the lower one is said to be 3 feet thick, the other 2 feet 8 inches, with a parting of fireclay.[†]

At Cousland there are said to have been six coals proved between Hadfast and Bellyford Burns, which were wrought in former times by driving in at the crop on the north brow of the former, and drained by a "day level" from the latter. These seams all dip to the north, and are the equivalents of some of the lower coals in this series, but the information is too scanty to enable them to be identified. More recently some of the same coals were worked in a pit near Hadfast, which was 99 feet deep, and the following is a section of the strata passed through.

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[*] *Communicated* by Mr. Williamson, Mining Engineer, Edinburgh.

[†] *The information* about the Fordel and Cousland coals I obtained from Mr. Dods, *of Cranston, Factor* to the Earl of Stair.

Section of Strata at Hadfast, near Cousland.

		FT.	IN.
	Various strata	27	0
	Coal	1	6
	Various strata	30	0
	Shale (roof)	3	0
"Wood" Coal	*Coal* (Parrot)	0	4
	Coal (hard)	2	0
	Stone mixed with coal	2	0
	Coal	1	8
	Various strata	30	0
	Shale (blaes roof)	7	0
"Hammersley" Coal.	*Coal*	1	0
	Stone	0	3
	Coal	1	8
	Stone	0	8
	Coal	1	3
	Depth of engine pit	99	4

I believe that the two coals given in this section, represent the "Bryans Splint," and Kailblades" seams in the Cowden and Newbattle collieries on the west side of the Roman Camp ridge.

C. *The Upper Limestone group and associated beds, from the Fourth Limestone to the base of the Millstone Grit.**—The strata included within this section of the Carboniferous Limestone series, as previously stated, contain three beds of marine limestone and four seams of coal above 1 foot thick, interstratified with sandstone, shale, and fireclay. The former generally throughout the coal-field are of a very impure character, and have never been wrought to any great extent; and, as in the case of the lower group of limestones already described, attain their greatest development along the south and south-west part of the district. Of the four coals in connexion with them, three lie between the fourth and fifth beds, and the other about 36 feet beneath the sixth or highest limestone. The former, along their western outcrop are known as the "Splint," "South Parrot," and "Wood" coals, and the latter on the coast at Joppa as "Allan's" coals. On the eastern side of the coal-field they have no distinctive names, but can be identified as the same seams from the position they hold with regard to the limestones. At the present time they are not worked in any portion of the district, although they have been so formerly.

The following section, taken from measurements of these strata, on the shore at Joppa salt pans, gives the thickness of each bed in detail:†—

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* See column, p. 73.

† This section is mostly taken from one given in Mr. Milne's Memoir on the *Mid-Lothian Coal-field;* the remaining portion is from one supplied me by Mr. Livingstone, of Portobello.

Section of the Upper Limestone Group at Joppa Salt Pans.

	FT.	IN.
Limestone (No. 6.)	3	0
Coal	0	6
Fireclay	9	0
Yellow sandstone	25	0
Fireclay	12	0
Grey sandstone	52	0
Coal	0	3
Sandstone	3	0
Fireclay	23	0
Coal	1	5
Fireclay	9	0
Argillaceous shale	15	0
Coal	0	6
Sandstone	4	0
Fireclay	10	0
Coal (Allan's)	2	0
Fireclay	8	0
Argillaceous schistus	5	0
Sandstone	4	0
Carried forward	186	8
Brought forward	186	8
Shale and fireclay	17	0
Coal	0	9
Grey sandstone	15	0
Argillaceous schistus	31	0
Sandstone	10	0
Fireclay	6	0
Limestone (No. 5.)	18	0?
Sandstone	12	0
Fireclay	9	0
Grey sandstone	20	0
Argillaceous shale	35	0
Ironstone	0	3
Fireclay and shale	18	0
Grey sandstone	15	0
Fireclay	2	0
Coal (Wood)	3	0
Grey sandstone	35	0
Total	433	8

There is no detailed account of the strata beyond this, but the South Parrot coal is said to lie 312 feet beneath the Wood coal, the last given in this section, and is 3 feet thick; and the fourth limestone is separated by about 100 feet of other strata from the South Parrot, and crops out in Joppa quarry. The following fossils have been collected by Mr. Richard Gibbs, of the Geological Survey, from this bed at the quarry,—*Actinocrinus, Productus giganteus, Bellerophon?* From the sixth limestone, which crops out on the shore at Joppa salt pans, the following have also been taken by the same collector,—*Archæocidaris Urii, Productus longispina, P. semireticulatus, Streptorhynchus crenistria, Bellerophon Urii,* and *B. decussatus.*

There is no section of these strata exposed between Joppa and Bilston Burn at Dryden, although the highest limestone has been wrought formerly at Coldcoats, near Edmonston. At Gilmerton, the Wood coal is 5 feet thick, and the South Parrot 3 feet 6 inches, and separated from the former by about 400 feet of other strata, and at Loanhead and Dryden they are respectively 2 feet and 3 feet thick, and the distance between them is 457 feet. At Bilston Burn, near Dryden, the upper limestones and the strata connected with them are laid bare and seen in an ascending section up to the base of Millstone Grit in the same order and position as on the shore at Joppa. These strata are not seen again till we reach Greenlaw, where the fourth bed is exposed in the small burn near Greenlaw Mains, but the others are not visible and have never been proved. Between Penicuick and Brunstone they are all seen several times crossing the North Esk River. The fourth bed crops out in Silverburn, near Penicuick House, and in the North Esk at the saw-mill. It is here in two beds, and contains the *Productus giganteus* in abundance, with *P. fimbriatus* and *P. longispina*, as at Joppa. From the saw-mill it bends round and crosses Harken Burn near Cornton, and from thence ranges along between Brunston Castle and the North Esk, and again crosses that river near Brunston colliery, ranging along on the east bank till it is lost under Auchencorth Moss. The fifth and sixth beds are also seen in the North Esk opposite Brunston, but the latter only at one place, in a small burn which runs into the North Esk on the east side near Auchencorth.

The South Parrot and Wood coals first cross the North Esk just south of the village of Penicuick, and, ranging along Birkinside Wood, cross Hare Burn, and bend round by Hurley Wood to Brunston, where they have been distinctly traced, as shown on the Geological Survey Map, between the fourth and fifth limestone beds, till they are lost sight of under the Moss.

In the section, fig. 18, these strata are shown lying under Auchencorth Moss and cropping out on the east side of it. Although neither the limestones nor coals have been seen at the point where the section crosses the eastern crop, there can be little doubt of their continuance, for immediately north of the line of section at Dykenook both limestones and coals are exposed crossing Black Burn, dipping to the north-west and west. In passing down the Black Burn between Dykenook and Penicuick many tumbled fragments of the limestone appear, evidently not very far out of place, but it was not possible to lay down the outcrop in a continuous line to where the same beds cross the North Esk at Valleyfield Mill. These are the fifth and sixth beds which are seen here, and contain the following fossils,—*Orthis resupinata, Strophalosia striata, Streptorhynchus crenistria, Rhynchonella,* and *Myalina,* &c.

From the North Esk at Valleyfield these strata strike in a north-east direction towards Auchindinny Mains, where the upper bed of limestone is seen in the burns between that place and Kirkettle, and following the contour of the coal-field along the southern outcrop the same bed crosses the South Esk between Carrington and Arniston, lying immediately below the red sandstones which represent the Millstone Grit. The exact position of the other beds is not known here, neither have the coals which are connected with them been proved, so that there is no information to enable me to lay down the outcrop on the map between Temple and Penicuick.

On the east side of the coal-field, although these strata are never seen in any section except on the shore between Musselburgh and Prestonpans, they have been proved in the collieries of Cowden near Dalkeith, and Wallyford, and they were also cut through in the New Mills level. The two following sections* at these places give the thickness of each bed, and by comparing them with the section on the west side of the coal-field at Joppa each bed of coal and limestone can be identified.

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* The section of the Wallyford measures was given to me by Mr. Williamson, *Mining Engineer,* of Edinburgh, and that of Cowden, by Mr. Alexander Gordon, of *Cowden colliery.*

Sections of the Upper Limestone Group at Wallyford and Cowden Collieries.

Cowden Colliery and New Mills Level.	FT.	IN.	*Wallyford Colliery.*	FT.	IN.
Limestone (No. 6.)	2	5			
Hard shale	9	0			
Red sandstone	24	0			
Shale and ironstone	7	0			
Coal	1	8			
Sandstone	19	0			
Shale	1	0			
Coal	0	6			
Sandstone	15	3			
Coal	1	2			
Shale and sandstone	76	6	Shale	3	6
Limestone (No. 5.)	2	11	*Limestone* (No. 5.)	1	9
Sandstone and shale	48	0	Sandstone and shale	93	2½
Coal	1	9	*Foul Parrot Coal*	0	6
Shale	6	0			
Sandstone	46	0	Sandstone and shale	56	5
Shale	60	0			
Sandstone	25	0	Sandstone	33	10
Shale, with streaks of coal	19	9	Sandstone and shale	17	0
Alternate beds of sandstone and shale	77	0			
Coal	3	0	Fireclay	3	3
Grey sandstone and shale in bands	8	0	Sandstone bands	9	4
Coal	1	5	*Shale mixed with coal*	1	9
Sandstone	84	0	Sandstone and shale	11	8
Limestone	0	4	*Limestone*	0	4
White sandstone	12	0	Sandstone and shale	11	11
Shale	2	0	Sandstone	101	2
Coal	0	4			
Shale and sandstone	3	0	Sandstone and shale	14	2
Sandstone in beds	7	0	Fireclay	2	4
Shale	0	6			
Coal, fine splint	1	9			
Sandstone bands	6	0			
Shale and ironstone	7	0			
Sandstone	94	0			
Limestone (No. 4.)	4	8	*Limestone* (No. 4.)	1	6
	678	11		363	7½

In these sections there is another thin bed of limestone 4 inches thick, but it is not met with in the Joppa section. It will be also observed that there is a great discrepancy in the intermediate strata; that they are much thicker at Cowden than at Wallyford, probably due to the beds of sandstone, which are throughout the district very inconstant.

I have stated previously that these strata are exposed in section on the coast between Musselburgh and Prestonpans. The fourth bed of limestone crops out at the west end of the latter town, and is 1 foot 6 inches thick, and contains the following fossils, obtained by the collector in company with Mr. Salter:—*Productus giganteus*, *Bellerophon decussatus*, and a small abundant *Chemnitzia*, or allied genus, of a slender shape, with numerous closely turrited whorls, and a species of *Macrocheilus*. The fifth bed is seen on the shore opposite Prestongrange, and is in two divisions, separated by calcareous shale and fireclay. The following fossils were obtained from it:—*Productus giganteus*, *P. longispina*, *Streptorhynchus crenistria*, *Spirifer trigonalis*, cup corals (*Aulacophyllum*?), stems of *Poteriocrinus*. The sixth bed occurs opposite Drummore on the coast, from which there have been collected the impressions of a sea-weed, known under the cognomen of "*Caudagalli*," with stems of *Actinocrinus*, *Poteriocrinus*, &c.

CHAPTER IX.

THE MILLSTONE GRIT.

THIS division of the Carboniferous formation has never before been classed as a separate group in any map or memoir published of this district, although the thick series of sandstones and conglomerates which here represent it have been noticed. Mr. Maclaren, in his "Sketch of the Geology of Fife and the Lothians," p. 70, refers them to the age of the New Red Sandstone, and adds, "*but less recent.*" Mr. Milne, in his "Memoir on the Mid-Lothian Coal-field," correctly shows that this is erroneous, and that they belong to the Carboniferous epoch, but includes them in the limestone group of that formation. By referring to the Geological Survey Map[*] and the sections, Plate I., and also the vertical section, fig. 17, it will be seen that these rocks occupy an intermediate position between the Carboniferous Limestone series and the Coal-measures, which lie in the centre of the coal-field. On the western outcrop they are seen on the shore opposite Joppa salt pans; and from the high angle at which the strata here dip, the narrow strip which they form on the map is nearly the total thickness of the rocks, and this continues inland to the large fault near Gilmerton. On the south side of this fault they strike along the valley of the North Esk River by Lasswade to Hawthornden and Roslin, where they form high cliffs of coarse red sandstone and conglomerate on each side of the river, lying immediately under the coals of Whitehill in a nearly horizontal position. From Roslin they gradually bend round by Kirkettle and Shewington to the South Esk River between Carrington and Arniston Mains, where they possess the same character as at Hawthornden, consisting of red and white sandstone and quartz conglomerate.

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[*] Since the map was published I have seen the same series of rocks in Fife, on the coast between Dysart and Kirkcaldy, where they are more fully developed. Whilst this Memoir was in the press, I visited the Mid-Lothian Coal-field again, and have drawn in the boundaries of the Millstone Grit with the Carboniferous Limestone series and the Coal-measures with greater accuracy.

On the eastern outcrop these rocks are seen on the coast at Westpans, near Musselburgh, and their position here is well marked, lying immediately below the lowest beds of coal, which are the equivalents of the true English Coal-measures, and above the highest (No. 6) bed of limestone in the Carboniferous Limestone series, which crops out to the east of Westpans. From the coast these sandstones strike inland by Carberry Mains and Longside to the large fault at Cowden. On the south side of this fault they were cut through in the New Mills Level, near Dalkeith, but were here found to be of much less thickness than on the west side of the coal-field. The following two sections, taken from actual measurements of these rocks at Joppa salt pans and the New Mills Level, show the relative thickness of the Millstone, Grit on the east and west sides of the coal-field.*

Sections of the Millstone Grit at Joppa, and the New Mills Level, near Dalkeith.

	Joppa.	FT.	IN.	*New Mills Level.*	FT.	IN.
	Coal	10	6			
	Fireclay	1	6			
Millstone Grit.	Sandstone	115	0	Sandstone	110	0
	Fireclay	4	0	Shale	9	0
	Coarse sandstone	56	0	Sandstone	88	0
	Fireclay	5	0	Sandstone	5	0
	Coarse sandstone	23	0	Fireclay and shale	19	0
	Fireclay	11	0	Sandstone	6	0
	Coal	0	6	Sandstone	3	0
	Coarse sandstone	55	0	Sandstone	3	0
	Fireclay	3	0			
	Argillaceous schist	10	0			
	Fireclay	3	0			
	Coarse sandstone	35	0			
	Fireclay and sandstone	33	0	Shale	31	0
	Coarse sandstone	20	0			
	Fireclay	9	0			
	Coarse sandstone	12	0			
	Fireclay	3	0			
	Coarse sandstone	8	0	Sandstone	3	0
	Fireclay and ironstone	39	0	Shale	18	0
	White sandstone	59	0	Sandstone	42	0
	Fireclay and ironstone	5	0	Hard shale	7	0
	Coarse sandstone	13	0			
	Fireclay and ironstone	8	0			
	Yellow sandstone	114	0			
	Fireclay	10	0			
	White sandstone	42	0			
	Fireclay	44	0			
	Coarse claystone	32	0			
		771	6		344	0
	Limestone (No. 6)	3	0	Limestone	2	5

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* *Both these sections are given in Mr. Milne's Memoir on the Mid-Lothian Coal-field.*

It will be seen from these sections that the sandstones diminish very greatly on the east side of the coal-field, and also that the whole of the rocks between the Coal-measures and the Carboniferous Limestone series become much thinner. Whether all the beds marked fireclay in the first section are so may be doubted. It is probable that many of them are ordinary shales, similar to other strata in the Carboniferous series.

A detached portion of the Millstone Grit, as shown on the Geological Survey map and section, fig. 18, lies in the middle of the narrow trough of the Carboniferous Limestone rocks at Auchencorth Moss, between Brunstone and Mosshouses. It is here of the same character as in other parts of this coal-field already described, and consists of coarse red and white sandstone and conglomerate, which may be seen in ascending Hare Burn, 2 miles south of Penicuick.

CHAPTER X.

THE COAL-MEASURES.

I HAVE already stated that immediately above the sandstones and conglomerates, which have just been described as representing the Millstone Grit, there is another series of strata containing productive seams of coal, which are the equivalents of those which constitute the coal-fields in the south-western and midland counties of England, and also of the Newcastle and Durham districts. In the Mid-Lothian coal-field the true age has never before been assigned to these strata, and they have heretofore always been classed with the Carboniferous Limestone series of coals; but there is this marked difference between them, that in the Coal-measures there is a total absence of those marine limestone beds which are associated with the lower series of coals, all of which contain true Carboniferous Limestone fossils. This, coupled with the fact that the two formations are separated from each other, as in England, by a thick series of strata of sandstone and conglomerate (Millstone Grit), containing no workable seams, and that in the rocks above this series here are found the ordinary species of *Unio*, or rather *Anthracosia acuta*, Sby., the same being found in the English coal-fields. There is also a species of *Rhizodus*, of *Amblypterus*, and the *Megalichthys Hibberti*. These facts have caused them to be classed by the Geological Survey as Coal-measures. As developed in this district, they contain two groups of coals, and as shown on the Geological Survey Map and in the sections, Plate I., occupy the centre of the coal-field, and lie conformably on the strata below them. The higher group, however, does not extend over the same relative area as the lower; and on the south side of the large east and west fault which runs through Dalkeith Park, only the latter are present, the former having been removed by denudation.

1. *The Lower Group of Coals*—In the northern part of the coal-field along the west outcrop, these are locally known as the "Brunstone," and on the opposite side of the basin as the "Cowpits" coals, from their having been principally wrought at those places. At the former locality there are six seams, which are named the "Greymecham," "Salters," "Nine-feet," "Fifteen-feet," "Four-feet," and "Seven feet;" and at the latter the "Little Splint," "Five-feet," "Quarry," "Glass," "Barrs," "Three-feet," and "Six-feet" coals. The following sections give the thickness of each seam, and the intermediate strata on each side of the basin:—

Section of the Brunstone Coals at Joppa.

		FT.	IN.
1.	*Coal* (Greymecham)	3	7
	Sandstone	110	0
2.	*Coal*	2	0
	Fireclay "Salters"	4	0
	Coal	2	0
	Sandstone and shale	45	0
	Fireclay	18	0
3.	*Coal*	1	1
	Fireclay, "Nine-ft."	2	0
	Coal	5	6
	Shale	31	0
4.	*Coal*, "Fifteen-ft."	12	6
	Red sandstone	100	0
	Fireclay	8	0
	Sandstone and shale	15	6
5.	Coal, "Four-ft."	4	0
	Fireclay	6	0
	Sandstone	3	0
	Fireclay, with ironstone	20	0
	Sandstone	24	0
6.	Coal	1	3
	Fireclay	4	0
	Coal, "Seven-ft."	6	0
	Fireclay	2	6
	Coal	2	0
	Fireclay	1	6
		434	5

Section of the Cowpits Coals.

		FT.	IN.
1.	*Coal*, "Little Splint"	2	2
	Sandstone and shale	8	0
	Coal	1	4
	Sandstone and shale	1	1
	Coal	0	6
	Sandstone and shale	92	4
2.	*Coal*, "Five-ft."	5	6
	Shale, with sandstone	5	5
	Coal, "Quarry"	1	6
	Sandstone	138	0
3.	*Coal*, "Glass"	2	0
	Sandstone and shale	48	0
4.	*Coal*, "Barrs"	4	0
	Sandstone and shale	24	0
5.	Coal, "Three-ft."	3	0
	Shale	9	0
6.	*Coal*, "Six-ft."	4	6
	Fireclay	12	0
		362	4

The coals given in the Brunstone section crop out on the west side of the coal-field, on the shore at Joppa salt pans, and dip to the east at an angle varying from 45° to 60°. As shown on the map they strike inland through Glen Nurseries, crossing Niddry Burn, and pass on the east side of Brunstone House, at which place they are in a vertical position. From thence they continue south by Coldcoats, Woolmet, and Danderhall, till they are interrupted by the large dislocation near Gilmerton, known as the "*Sheriffhall*" fault.

On the east side of the basin the "Cowpits" coals rise to the surface at Musselburgh Links and Pinkie, and dip to the west at an angle of 10°. At the latter place they are intersected by two parallel faults running east and west, the first throwing down the strata on the south 5 fathoms, and the other 6 fathoms on the north side. South of this last fault the coals continue without interruption to Midfield, where another fault throws them down 7 fathoms on the north; and about half a mile farther south, at Cowpits, they are again shifted 16 fathoms further down on the south. Beyond this last fault the outcrops of these coals have not been proved, and none of them have been worked within a recent date. It is said, however, that the two seams which are seen in the burn near Smeaton are the "Barrs" and "Glass" coals, the strata dipping here a little north of west.

On the south side of the large "Sherriffhall" fault these same coals have been formerly wrought on the west side of the coalfield at Eldin, Bonnyrigg, Polton, and Barleydean, and are at the present time worked at Whitehill. There are four principal seams here which are known as the "Great Seam," "Rough," "Splint," and "Jewell" coals. The strata vary so greatly in thickness that it is hardly possible to identify each seam individually, but they are known to be the same as those at Brunstone and Cowpits, from the fact of their lying immediately above the Millstone Grit, which crops out in Hawthornden under the Whitehill coals, as shown in the No. 2 section, Plate I.

By referring to the map the three last of the above coals, viz., the "Rough," "Splint," and "Jewell" rise to the surface on their west outcrop at Melville Park, and between Lasswade and Bonnyrigg, and strike in a south-west direction to Hawthornden and Gorton, the dip of the strata being to the south-east at angle of 10°. The crop of the Great Seam is not known till we reach Rosewell, where it has been proved in Whitehill colliery. The following sections* give the thickness of these coals, and the intermediate strata at Polton and Whitehill:—

Section at Polton Engine Pit.

	FT.	IN.
Various strata - -	186	0
Rough coal - -	3	6
Various strata - -	33	6
Splint coal - -	2	6
Various strata - -	30	0
Jewell coal - - -	2	6
Total depth -	252	0

Section of Strata at Whitehill.

	FT.	IN.
Various strata - -	48	0
Great Seam - -	8	0
Various strata - -	57	0
Rough coal - -	3	6
Various strata - -	10	0
Splint coal - - -	2	6
Various strata - -	32	0
Parrot coal - -	4	0
Various strata - -	6	0
Jewell coal - - -	2	4
Total depth -	213	4

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* From a report by Mr. Geddes, Mining Engineer, Edinburgh.

These coals south of Whitehill are not known till we reach Barleydean, on the southern outcrop of the Coal-measures, but they probably curve round as shown on the map. Here the "Great Seam," "Rough," "Splint," and "Parrot" coals have been proved and formerly worked. They are intersected by a fault, which throws the strata down on the south-east side 7 fathoms.

East of Barleydean there are indications of some coals having been formerly wrought between Carrington and Redside, which, from the position they occupy, are no doubt a continuation of the same seams, as the red sandstones and conglomerates of the Millstone Grit series rise from below them in the South Esk River, near Arniston, the dip of the strata being rather to the west of north at an angle of 15°.

Along the eastern side of the coal basin, south of the Sheriffhall" fault, the crops of these coals have not been ascertained with accuracy. Their general line of bearing however, along the valley of the South Esk River by Prestonholm, Cockpen, Millhill, and Newbattle Abbey, and they were intersected by the New Mills Level near Dalkeith, where five thin seams of coal were found above the Millstone Grit sandstones, and which are no doubt the equivalents of the Whitehill seams, although much reduced in thickness. Some of them have, however, been wrought in former times at Newbattle, it is said by the monks of the Abbey, and there are numerous indications of these old workings on the surface at Millhill and through Newbattle.

The upper group of Coals.—These are separated from the lower group, just described, by about 200 feet of strata composed principally of sandstone and shale, with four thin seams of coal, and are locally known as the "Flat" coals in contradistinction to the "Edge" seams at Brunstone and Duddingston. They were formerly supposed to be unconformable to the other carboniferous rocks below them, an error which was first pointed out by Mr. Milne.* That they are conformable to the lower group is perfectly evident on the east outcrop, where the "Cowpits" seams, which have already been shown to be the same as those at Brunstone, rise gradually and at the same angle from beneath them.

There are six principal beds of coal in this group, and, as I have previously stated, they only occupy the northern part of the coalfield, and do not extend south of the Sherriffhall fault, which traverses the district near Dalkeith. They are named the "Clayknowes," "Splint," "Rough," "Beefie," "Diamond," and "Jewell" coals, the last but one, however, being very inconstant, and not continuous as a workable seam throughout the basin. As shown on the Geological Survey Map, the crops of four of the above are laid down along their western outcrop commencing on the shore between Musselburgh and Joppa salt pans, and strike inland through New Craighall, Shawfair, Newton Church, and Todhills, to Somerside, and are there cut off by the Sherriffhall fault. The eastern outcrop of the same seams is not so well ascertained, and they are often interrupted by faults. They rise to the surface on this side of the basin at Musselburgh Links and Pinkie House, where they are intersected by the two faults which were mentioned as affecting the lower group at the same place. South of these faults the "Jewell" coal crops out at Inveresk, and between the Midfield and Cowpits faults the same seam and the "Diamond" cross the Esk at the bridge of the North British Railway over that river. The latter slip, as previously stated, throws the strata down on the south-west side 16 fathoms, and consequently shifts the coals to the south-east, which continue through the north part of Dalkeith Park as far as Castlesteads. Somewhere near this place they must be intersected by a large fault, for the next locality where these coals appear is at Smeaton colliery, the "Jewell" seam being there 62 fathoms deep, and the "Splint" cropping out immediately east of the pit. As shown on the map, I think this fault must be a continuation of one which was proved near Newton House in the centre of the basin, to throw the strata down 6 fathoms on the south, but probably increases in size towards the east. It pointed in the direction of Castlestead, and there are indications of a disturbance of the strata at the point where it is laid down as crossing the Esk River, which may probably be caused by it. I was also informed by Mr. Gordon, the manager of the Cowden and Smeaton collieries, that a fault has been proved immediately north of Smeaton brickworks, but which has never been pierced, so that its amount of "throw" has not been ascertained. I think it is most probable that this is a continuation of the same slip.

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* Memoir on the Mid-Lothian Coal-field, p. 116.

South of Smeaton Colliery the crops of these coals have not been ascertained, but they are believed to continue in the direction of and as far as Cowdenfoot, where they are cut off by the Sherriffhall fault, although they have never been wrought up to it. It is known, however, that this fault intersects them here, for numerous borings have proved that the lower group on the south side of it are brought to the level of the upper group.

The following sections give the thickness of each seam and the intermediate strata, on the west side of the basin at Craighall, and on the east at Smeaton colliery:—

Section of the Upper Group of Coals at Craighall.

		FT.	IN.
1.	*Clayknowes Coal* -	3	0
	Sandstone and shale -	28	0
2.	*Coal* - - -	1	6
	Sandstone and shale -	135	0
	Sandstone (red and white) - -	135	0
	Shale - - -	4	0
3.	*Coal* (the "Splint") -	5	0
	Sandstone and shale -	45	0
	Ironstone - -	0	0½
	Sandstone - -	18	0
4.	*Coal* (the "Rough") -	4	0
	Shale - - -	42	0
	Sandstone and shale -	13	0
5.	*Coal* (the "Beefie") -	6	0
	Sandstone - -	36	9
	Grey bands - -	16	0
	Shale (red) - -	30	0
	Sandstone (red and white - - -	22	0
	Shale - - -	28	0
6.	*Coal* (the "Diamond")	6	0
	Sandstone and shale -	20	0
7.	Coal (the "Jewell") -	3	0
	Total thickness -	610	0½

Section of the Upper Group of Coals at Smeaton and Dalkeith.

		FT.	IN.
1.	*Coal* (the "Clay-knowes" - -	3	6
	Shale - - -	8	0
	Coal (soft) - -	1	0
	Sandstone and shale	83	0
2.	*Coal* - - -	1	3
	Red Sandstone and shale - -	44	2
	Shale, with *Unio* -	11	1
3.	*Coal* (the "Splint")	3	10
	Sandstone and shale	24	8
4.	*Coal* (the "Rough")	0	6
	Shale - - -	5	8
	Grey sandstone -	84	4
	Shale - - -	0	10
5.	*Coal* (the "Beefie")	3	6
	Shale and sandstone	7	9
	Sandstone - -	19	6
	Sandstone and shale	28	7
6.	*Coal* (the "Diamond") - -	0	10
	Sandstone and shale	10	6
	Shale - - -	7	9
7.	*Coal* (the "Jewell")	4	0
	Total thickness -	354	3

It will be seen from these sections that the strata vary considerably, and also that their total thickness is much less on the east side of the basin. The "Rough" and "Diamond" coals which are respectively 4 feet and 6 feet thick at Craighall, are not workable seams at Smeaton.

In the Smeaton section the bed of shale which lies immediately above the "Splint" coal contains in its lower past a band 3 inches thick made up entirely of *Unios.* This stratum, called the "Mussel bed" by the colliers, is very constant throughout the Coal-measure basin, and lies above the same seam at Craighall on the west side of the coal-field.

Above the "Clayknowes," the highest seam of coal in the upper group, there are 267 feet of strata consisting principally of red sandstone and shale, which contain two thin beds of coal, the lowest 1 foot 10 inches, and the other 4 inches thick. These strata occupy the centre of the coal basin, and lie in the southern part of Dalkeith Park against the Sherriffhall fault. The highest bed is red sandstone, proved to be 61 feet thick, and no coals are known above it, but there is no doubt that it belongs to the Coal-measures formation, as it contains the same plants, *Stigmariæ,* &c., and is quite conformable to both groups of coals. These are undoubtedly the equivalents of at least part of the red series of rocks on the opposite shore of the Firth between Leven and West Wemyss, and it is not unlikely that they represent the sandstones and red shales that form the uppermost Coal-measures of some of the English coal-fields, as, for instance, those of North and South Staffordshire.

H. H. H.

CHAPTER XI.

INTRUSIVE IGNEOUS ROCKS.

IN the preceding chapters the formations have been described in stratigraphical order, from the oldest upwards, including in their proper chronological place such trap rocks as can be shown to have been ejected contemporaneously with the deposition of the strata among which they occur. But these by no means include all the igneous rocks of the district; there is, besides, a vast number to which no exact date can be assigned, since they are found traversing indifferently all the other rocks alike aqueous and igneous. It would be rash, however, to assume from this circumstance that they form, as a whole, the latest group of rocks in the neighbourhood. They undoubtedly belong to many different periods of eruption, and there seems every reason to believe that they are to a large extent of Carboniferous age.

Before entering into the details of some of the more important and interesting of these intrusive traps, one or two facts relative to their general disposition deserve attention. At a first glance it is evident that these rocks are not equally distributed over the district embraced in the present map, and on examination it will be found that, with the exception of the trifling greenstone dyke at Niddry, the prolongation of the Haddingtonshire one at Prestonpans, and that in the Esk at Carlops, no trap occurs east of the axis of the Pentlands, while west of that axis it is profusely abundant, both intrusive and contemporaneous. Again, it will be observed that the intrusive masses range themselves sporadically, but in a general north-east and south-west direction, that is, parallel to the Pentland axis and its flanking faults, and to the strike of the country. For example, the Ratho and Kirknewton greenstones form a pretty distinct group. North-east from these lies the series which ranges from Corstorphine to Queensferry, and then strikes north-east into Fife. Another sporadic assemblage clusters round Binny Craig, and extends likewise north-east to Queensferry. It will be seen, moreover, that although these traps correspond in their direction, as a whole, to the general strike of the rocks of the district, they do not in every case follow the same rule individually. Their tendency is of course to keep between the lines of bedding, and hence they have themselves not unfrequently a bedded aspect.

But in many instances they cut through the strata without reference to dip or strike, though even in their irregularity they do not widely depart from the north-east and south-west line. Lastly, it will be observed that many of the minor faults run in a general easterly and westerly direction, and that the trap-dykes preserve the same course, striking across the older traps and their associated strata.

It would be premature, from the partial basis of evidence furnished by the present Sheet to generalize much on the intrusive traps. It is, I think, presumable, however, that the east and west trap dykes belong to a later period than any of the other igneous rocks, with the exception of some at Arthur's Seat, to be afterwards described, and that they are consequently newer than any part of the Carboniferous series which they traverse throughout. That they are connected with east and west lines of fault is abundantly evident; and as these faults have cut through the intrusive traps without being interrupted by them the probability is that both faults and dykes are of later date.

In attempting a description of the intrusive rocks of such a trappean district as a large part of the area embraced by the present Sheet, it is of course only possible to select some of the more important and interesting instances. In doing so it will be best to follow a stratigraphical order, beginning with the Silurian upwards. It is hardly necessary to remind the reader that this arrangement must not be regarded as at all a chronological one.

INTRUSIVE TRAPS IN SILURIAN SERIES.—In the two Lower Silurian patches which come into this Sheet no igneous rocks occur. But they are met with in great abundance both in the Peeblesshire Hills to the south, and in the Lammermuirs to the east. They are almost always felspathic, greenstone or basalt being exceedingly rare. The igneous rocks of the Lammermuirs will be described in the Memoir accompanying Sheet 33.

In the Upper Silurian rocks of the Pentland Hills, notwithstanding the great thickness of overlying unconformable felstones, the only intrusive trap is the greenstone at Bevelaw. It is a hard, compact, sparingly amygdaloidal rock, and occurs as two or more dykes separated by hardened shale and grit. Its strike corresponds with that of the beds among which it occurs, being from S.S.W. to N.N.E.

INTRUSIVE TRAPS IN OLD RED SANDSTONE SERIES.—In this formation, too, notwithstanding the abundance of contemporaneous felstone, intrusive trap is rare. With the exception of a small felstone vein in the Upper Conglomerate at the linn, Habbie's Howe, the dykes consist of a dull reddish brown or chocolate-coloured greenstone. Two may be seen in the Esk between Carlops and the Reservoir, and others occur on the *Lyne Water.*

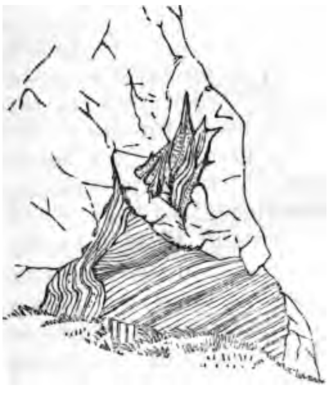
INTRUSIVE TRAPS IN CARBONIFEROUS SERIES.—These are very abundant to the west of the Pentland axis; they occur also at the north end of that axis in the hills about Edinburgh, but only one or two instances are known of their occurrence in the great carboniferous valley of Mid Lothian. With the exception of the small felspathic dykes at Granton and those on the Linhouse Water above Midcalder, all the intrusive traps in this series are augitic. The map gives the position and area of all that have been observed, but a few present features worthy of special remark.

Castle Rock, Edinburgh.—This is a very compact phonolitic basalt. Its contour is oval, with steep sides, and the mass has thus a strong resemblance to a volcanic neck, that is, the solidified lava filling up an old vent or crater. It lies, as the reader will observe, between the contemporaneous ashes and lava-form traps of Arthur's Seat and Calton Hill on the one side, and Craiglockhart Hill on the other, and not improbably formed the centre of eruption from which these igneous rocks were ejected. The south-eastern side is smoothed and striated vertically, owing to the downward movement of the long fault which passes through this point.* (See *ante*, p. 20.)

The intrusive greenstones of St. Leonard's, Salisbury Crag, (fig. 19), and the Dasses have been already described (pp. 21, 22), and similar rocks occur at Lochend. Numerous dykes traverse the Lower Carboniferous Sandstones on which the town of Edinburgh stands; those of which any details could be obtained from well-sinkings, drains, old quarries, &c. have been inserted on the map. Those in the Water of Leith have been well known since the days of Hutton.

Fig. 19.

GREENSTONE ENVELOPING SANDSTONE, SALISBURY CRAIG.



On the shore at the western breakwater, Granton, an instructive section is displayed of about a a dozen light-coloured felspathic greenstone dykes, traversing the sandstones and cut through by faults.

Corstorphine Hill consists of a crystalline hornblendic greenstone, disposed as a bed dipping westerly. It occupies a higher position than the sandstones of Craigleith and Blackhall, and rests on sandstones and shales, which may be seen at many places along the base of the eastern escarpment. The southern limb of the hill bends eastward, owing to a change in the strike of the underlying beds. North of Corstorphine Hill several dykes and intrusive beds may be seen on the shore and at the lower part of the river Almond. A greenstone mass of considerable size, with a dip similar to that of Corstorphine, ranges from the shore a little west of the mouth of the Almond, southward to West Craigs.

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* See this section, figured by Dr. Greville in Lord Greenock's paper. Trans. Roy. Soc. Edin., vol. xiii. p. 39, *et seq.* His lordship explained the smooth surfaces by supposing that the trap came up in a semi-solid state and so took the impress of the rocks across which it moved. Mr. Maclaren referred them to the downward movement incident to the shrinking of the cooled mass; Geol. Fife and Loth., p. 58.

Mons Hill, Queensferry.—This enormous mass of greenstone rises to a height of 386 feet above the level of the sea, and seems to form part of the series which is prolonged by Inch Garvie into Fife. Its internal structure has sometimes a bedded aspect (as may be seen in the road cuttings south of Leuchold), which would lead to the inference that the whole must be an interstratified mass, but for its amorphous disposition, when viewed in relation to the strike of the stratified masses on its southern side, and the indurated texture of the shales which rest upon it on the shore. It shows in some places, especially along its northern and southern margins, large crystals of augite and pink felspar, which impart a granitoid appearance. The little greenstone bed which occurs below it at Hound Point, presents an interesting junction with sandstone and shale (figs. 20 and 21).* From Mons Hill south-westward a sporadic group of greenstones occurs among the

Fig. 20.

GREENSTONE INTRUDED AMONG SANDSTONES AND SHALES, HOUND POINT, SOUTH QUEENSFERRY.

(Side View.)

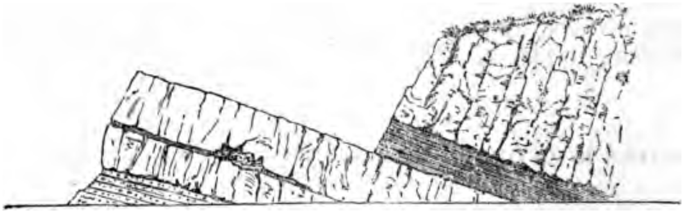
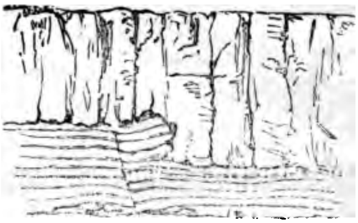


Fig. 21.

(Front View.)



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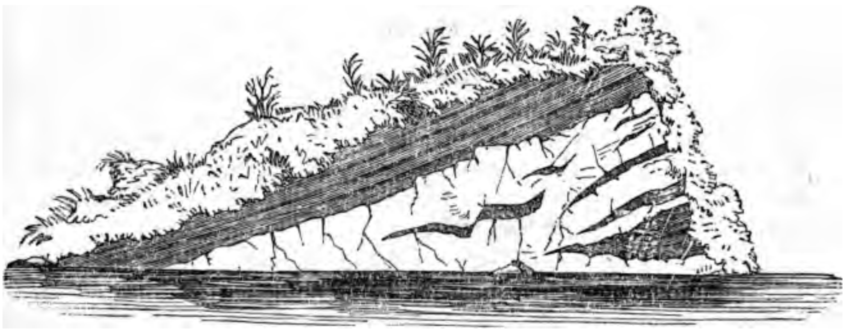
* *See* Cunningham, "Geology of the Lothians," Mem. Wer. Soc., vol. vii., *plate ix., where* another sketch of this instructive section is given.

strata that immediately underlie and overlie the Queensferry limestone. Some interesting sections of this series occur in the cuttings of the Edinburgh and Glasgow railway east of Winchburgh tunnel; fragments of shale are there seen enveloped in the greenstone which sends twisting veins into the contiguous strata.

Ratho and Kirknewton.—This group presents the usual features. Ratho Hill consists of a granular crystalline greenstone containing zeolitic cavities, and sometimes traversed by branching veins of a lighter coloured greenstone. The north and south limb dips west, but the other appears to break through the strata irregularly, and this change in the direction, along with the uneven outline of the eastern side, gives the whole mass a strong resemblance to a gouty leg stuck awkwardly upon a somewhat ungraceful foot. Dalmahoy and Kaimes Hill consist of a compact fine-grained greenstone, lying as a rudely columnar bed, between Lower Carboniferous sandstones and shales, which may be seen along the side of the north escarpment. The trap bosses about Kirknewton are all of greenstone. Near Midcalder, however, two irregular intruded masses of felspathic trap occur in the channel of the Linhouse Water. They greatly alter the contiguous strata and almost porcellanize the shales. Indeed, as a rule, the intrusive felspathic rocks in this district produce a much greater alteration in the strata than the augitic rocks. The lower of the two masses in the Linhouse Water assumes various aspects, sometimes resembling a felspathic amygdaloid, sometimes a porphyry, and sometimes an ash. Some of the sandy plant-bearing shales which it intersects have also an ashy appearance and are decidedly felspathic. The upper mass is considerably larger. It consists of a pale yellowish felspathic rock, sometimes porphyritic and amygdaloidal, and approaching a greenstone in places. The subjoined figure represents one of the sections on the side of the stream, a little below Contentibus. It is possible that both these felspathic rocks may be connected with the felstone of Corston Hill, which is certainly an inter-

Fig. 22.

FELSTONE INVOLVING SHALES, LINHOUSE WATER, A LITTLE BELOW CONTENTIBUS.



bedded trap of Lower Carboniferous age occurring among strata considerably higher than those below Contentibus. In this case the relation might be compared with that pointed out between the Castle Rock and Arthur's Seat.*

A prolongation of the Kirknewton group of traps may be traced to the south of Corston Hill in the detached greenstones of Auchinoon and Colzium. The line of the whole series, it will be observed, runs north-east and south-west, no augitic traps for some distance occurring immediately to the east or west.

Binny Craig.—This is one of the most prominent hills in Linlithgowshire, since it rises with a steep western face to a height of 718 feet above the sea. It consists of a compact basalt, intruded partly as a dyke, and partly as an irregular sheet among the shales, which here represent the Queensferry or Burdie House Limestone. At the top of the cliff near the highest point there is a remarkable cavity containing anthracite in aggregated round pencil-shaped stems; irregular layers of the same substance are found coating some of the joints, and the rock when freshly broken emits a strong bituminous odour. The latter peculiarity has been already adverted to. It characterises the whole group of greenstone masses which diverge to the south-west from Binny Craig. In connexion with these facts I would also refer again to the occurrence of petroleum in the chinks of the sandstone in Binny Quarry, not many yards distant from the end of the eastern prolongation of Binny Craig. The Craig itself has broken through the centre of one of the numerous Linlithgowshire anticlines, and the shales at its south end are contorted and hardened by the irregular trap bosses that have been squirted through them.

Raven Craig.—This mass of greenstone, though not included in the present Sheet, has been already referred to as abruptly protruding among the limestones, basalts, and ashes of the Carboniferous Limestone group between Bathgate and Silvermine. It has a strongly bituminous odour when a fresh surface is broken as in the quarry, between Clinkingstone and Bathgate. On the roadside, too, between Limefield and the Knock it assumes an amygdaloidal structure, and the cavities contain a quantity of soft bitumen. At its west end it has involved a large mass of limestone, which has been quarried. The Knock is a greenstone dyke dipping steeply to the east, and running at right angles to the general direction of the dykes in this neighbourhood. It may be traced into the South Mine lime quarry, where it thins away to a narrow vein adhering as a pellicle to the unquarried face of limestone.

East and West Trap Dykes.—These do not require any detailed enumeration, their position being sufficiently indicated on the map. I may remark, however, that they are most abundant in the trappean region between Bathgate and Linlithgow, and that there they occur chiefly along the bottom of the transverse valleys which cross the hills at right angles to the strike of the strata. These valleys appear in most cases to coincide with lines of fault of greater or less amount, and hence the trap dykes ought probably to be assigned to a period posterior to the faulting of the district. Where the dykes traverse a trap-ridge, it is interesting to observe that they retain their distinctive features, and commonly stand out prominently, while the surrounding trap has weathered away. This is especially noticeable on the Riccarton Hills, also at Kipps, and to the west of the cottage at the Knock Hill. As an instructive example of the persistency of a trap dyke the observer may advantageously trace that which occurs at Nancy's Hill, south of Linlithgow, and extends westward through limestones, greenstones, and coals, into Stirlingshire, at the Canal aqueduct over the Avon. Another characteristic example is the dyke at Prestonpans, which may be traced eastwards for 6 or 7 miles into Haddingtonshire.

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* *There is no locality within easy reach of Edinburgh which presents the learner with so many instructive sections as the channel of the Linhouse Water for about two miles above its junction with the Almond.*

The only dyke in the coal-basin of Mid Lothian is that at Niddry, near Portobello, which has a general east and west direction across the strike of the higher inclined strata of the Edge-coal series.*

CHAPTER XII.

FAULTS.

It is seldom that the series of faults inserted on a geological map conveys a just impression of the actual number in nature. Only in a coal-bearing district, where the underground geology has been laboriously ascertained, do we usually obtain an insight into the really broken and fissured character of a district which, to judge from its surface, we should otherwise have pronounced regular and undisturbed. Hence the reason that coal basins generally appear the most faulted parts of a geological map, although in actual nature they may be much less so than many parts of the contiguous country which have not been so thoroughly explored. It will be observed that the present Sheet forms no exception to the general rule. The Edinburgh coal-field, as there mapped, contains almost two-thirds of the faults inserted on the Sheet. They are numerous also in the coal-field of Borrowstounness.

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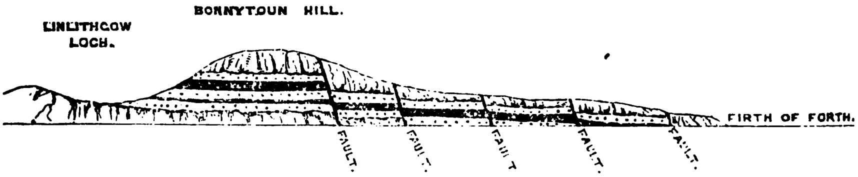
* A full and illustrative series of specimens of these intrusive rocks is deposited in the Museum of Economic Geology, Jermyn Street; a similar set being ready for display in the Industrial Museum, Edinburgh. See Descriptive Catalogue of Rock Specimens in Mus. Econ. Geol., 2nd edit., pp. 354–359.

To attempt a detailed enumeration of the faults in this Sheet would be superfluous. Those which deserve remark in the coal-fields have been already noticed, and I shall here describe one or two in the older rocks. Even on a first glance it is plain that the faults of this district group themselves naturally into two series, one more or less at right angles to the strike of the beds that is east and west, or from south-east to north-west; the other, usually of greater magnitude, in long parallel north-east and south-west lines. To the former class belongs by far the larger number, including those of the coal-fields. In the Mid Lothian basin the prevailing direction of downthrow is to the north. The same is the case at Borrowstounness, where, by a succession of step-like faults, the greenstone, which caps Bonnytoun Hill at a height of 500 feet above the sea, is brought down to the sea-level in the short space of a mile. This structure is shown in fig. 23. The greatest amount of throw known in this coal-field is about 120 feet; the greatest in the Edinburgh field is 480 feet, the direction of downthrow in each case being towards the north.

Fig. 23.



The north-east and south-west faults lie almost wholly along the axis of the Pentlands. In place of cutting across the strike of the country as the other faults do, they run parallel to it. Flanking each side of the anticline, their effect has been to depress the Carboniferous strata against the older rocks of the hills, so that on the west side their downthrow is to the west, and on the east side to the east. The long line of dislocation, which extends from the sea at Portobello to beyond Carlops in Peeblesshire, is probably the largest fault in the district. It has thrown out nearly the entire thickness of the Lower Carboniferous Series on the east side of the Pentlands and brought down the Carboniferous Limestones and subjacent beds at high angles and even with a reversed dip against the Old Red Sandstone. The amount of throw cannot be ascertained with exactness; it depends on the estimate we form of the thickness of the Lower Carboniferous rocks. If we allow the depth of strata between the Burdie House Limestone and the top of the Old Red Sandstone to be 3,000 feet,* that would comprise the extent of downthrow at

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* The thickness of the Carboniferous strata below the Burdie House Limestone on the east side of the Pentland chain cannot be ascertained, owing to the long fault and partly also to the depth of drift which obscures the country. We can form an approximate estimate, however, from the region to the west, between the Pentland and the Bathgate Hills. The strata, as there exposed, cannot be less than 3,000 feet, and are probably more.

Gilmerton, but at Carlops we should have to add to this the thickness of that part of the Old Red series which is there wanting. The fault that skirts the largest patch of Silurian strata and enters the head of the Logan Valley is of much less extent. It has depressed the Upper Old Red and Lower Carboniferous beds against a lower part of the series, and towards its north-east end it brings down the felstone of North Black Hill against a small patch of Silurian shales, the junction being seen at Habbie's Howe. This fault appears to die out in North Black Hill. The next fault in a north-westerly direction occurs at Bevelaw, whence it flanks the hills in a wavy line as far as Arthur's Seat. For the first mile or two along the north-west slope of North Black Hill its course is pretty clear, and it there depresses Lower Carboniferous sandstones at high angles against Silurian strata and felstones (Fig. 24). Beyond this, however, its line, owing to the want of adequate sections and the depth of drifty soil, cannot be precisely ascertained, and is expressed on the map by a broken line. Its effects, however, continue to be visible. At Warklaw and Torduff, for instance, it has repeated two of the felstone beds of the hills, as I have already shown (p. 12). In the Braid Burn, Lower Carboniferous sandstones come close up against it dipping west by south at 30°. At Egypt, also, similar strata dip away from it at 30°; and we may perhaps refer to its agency the remarkable truncation of the south side of Arthur's Seat, so similar to the truncation on the north side of that hill, which undoubtedly is due to a fault (p. 26). The next and last of these parallel faults begins near the south-west end of Warklaw Hill, and runs thence by Colinton to the Castle Rock. It is visible in the bed of the Kenleith Burn, where it throws down Lower Carboniferous sandstones at a high angle against the felstone of Warklaw Hill; its effects at Colinton are visible in the *highly tilted* sandstones, and though

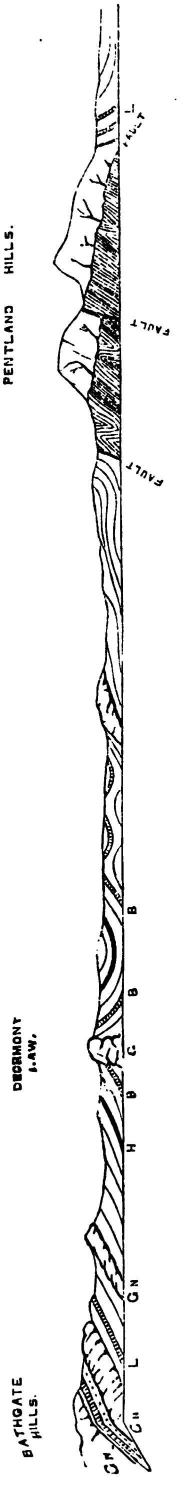

Fig. 24.—SKETCH-SECTION FROM THE BATHGATE HILLS ACROSS THE PENTLAND HILLS.

Gn. Greenstone. L. Carboniferous Limestone. H. Houston Coal (see p. 42). B. Burdie House or Queensferry Limestone. The Pentland Hill felstones are seen to the right overlying the inclined Silurian Shales, and truncated by the fault which brings down the Carboniferous Limestone series of the Edinburgh Coal-field.

obscured north of this point, it still continues a powerful fault at Edinburgh, as already shown (*ante*, p. 20).

In fine, when we reflect upon the extent of depression produced by these faults, we see at once that the Carboniferous rocks must formerly have stretched across the area of the Pentland Hills, and that it is to the agency of these dislocations, aided subsequently by an extensive denudation, that the older rocks of that chain are visible. To the nature and extent of this denudation I shall now advert.

CHAPTER XIII.

PROOFS OF EXTENSIVE DENUDATION.—LATER ROCKS OF ARTHUR'S SEAT.

IF the observer will place himself on any of the more prominent hills of the district he will see everywhere around him proofs of extensive denudation. The abrupt solitary crags rising from smooth-swept undulating plains, the long narrow valleys, the truncated ends of strata as in Salisbury Craigs shooting up into mid-air, the deep gorges that breach the highest hills even at the water-shed of the country, and, above all, that peculiar rounded undulating aspect of the whole landscape, convince him that the region has suffered much from the long-continued action of alvading forces. Nor is the impression lessened when he begins to analyze the structure of the district; he sees from the evidence of the rocks proofs of enormous dislocations, but fails to detect any trace of them on the surface; fissures and faults, which but for a denuding process would have left the country an impassable network of interlacing precipices and ravines, have been all planed down until not even a geologist would suspect any trace of their existence; truncated ends of once prolonged strata everywhere occur; anticlinal ridges have been worn down into valleys; and throughout the whole area, the hard traps stand out prominently, while the surrounding sedimentary rocks have disappeared.

If it was sufficiently clear from the structure of East Cairn Hill (*ante*, p. 19) that the Carboniferous series once extended continuously over the site of the Pentlands, the fact is amply confirmed by the evidence of the parallel faults given in the preceding chapter. The entire thickness of the Carboniferous series in this part of the country is probably over 8,000 feet. Assuming it, however, to be only 5,300, this would give an amount of material removed from the Pentland Hills alone (14 miles long by 3 broad) equal to about 42 cubic miles. But this would be much under the truth, and would represent besides only a fraction of the denudation of the country. To take another instance,* the limestone ridge of the Roman Camp Hill extends for about 5 miles with an average breadth of, say, half a mile. The thickness of strata removed from this ridge is about 3,000 feet, and their entire amount is therefore equal to 209,088,000,000 cubic feet, and this again only represents the denudation of a narrow strip of ground. The whole of the surrounding country has likewise suffered, and it might perhaps be possible to calculate roughly the depth of material removed from the area of the Lothians. There seems no reason to doubt that it is at least as extensive as the well-known denudation of the Sussex Weald. Bearing these facts in mind, the observer will cease to wonder that so much of the geology of the Lothians is fragmentary and disconnected. His surprise will rather be to find that so intelligible a series of rocks has been left, and that even after the destruction of such a vast extent of Carboniferous strata, the story of the Carboniferous period can be made out so well.*

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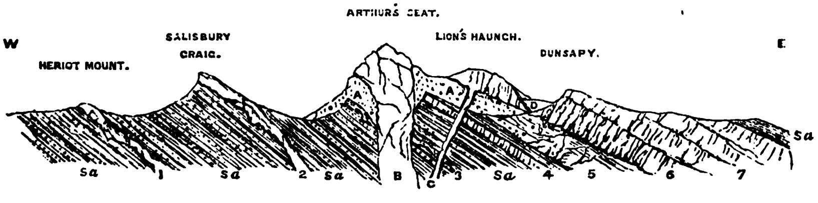
* It may aid the conception of this enormous denudation, to compare it with the existing mass of the Pentland Hills. If we suppose the chain to have at present a *general elevation of* 1,000 feet over the surrounding country (though this would be an *exaggeration), then* the amount of removed material would surpass by more than *five times the existing* mass of the Pentland Hills.

This great denudation must evidently have required a long lapse of ages for its completion. There is no evidence in the district to limit it even to Secondary times, for above the highest of the Carboniferous series no Palæozoic or Secondary strata supervene, and the process of abrasion may have been going on during the whole or part of these periods. Rocks of older secondary age occur north of the great granitic barrier of the Grampians along both the eastern and western shores of the island. They occur likewise on the south side of the Silurian hills of South Scotland at Carlisle. But there is no evidence of their existence between these points. Of the condition of Central Scotland, therefore, during the long interval represented by the Secondary formations we have no trace at all. The denudation had been going on, and was indeed well nigh as complete as it is now, when the volcanic forces which had been so vigorous in the old Carboniferous times broke out again on the site of an old volcano. The products of this later eruption have been fortunately in part preserved, and form the upper part of Arthur's

Fig. 25.

SKETCH-SECTION OF ARTHUR'S SEAT (EAST AND WEST LINE THROUGH SUMMIT). The Figures have the same reference as in Fig. 4.



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* The Upper Silurian and Lower Old Red Sandstone must of course have undergone a process of abrasion previous to the deposition of the Upper Old Red and Carboniferous series. But there is not sufficient evidence in the area embraced by the present Sheet for the discussion of this point, which will therefore form part of a subsequent Memoir.

Seat. The accompanying figure represents the structure of that hill, in an east and west section, through the summit. It shows at a glance that there is an utter unconformity between the Carboniferous traps and these later ones, and that this unconformity must represent a very great interval, I shall here briefly attempt to show.

I may remark, first of all, that there is no unconformity in any part of the Carboniferous series of this district. It is a consecutive series from bottom to top. Any strata, therefore, which rest unconformably on a part of this series must be later than the whole of it. It has been already shown that Arthur's Seat lies on the eastern side of the Pentland axis, and that this axis was at one time covered with Carboniferous rocks, to a depth of perhaps 8,000 feet. As these rocks are prolonged northwards into Fife, it follows that the Carboniferous part of Arthur's Seat must in like manner have been submerged below this great accumulation of subsequent strata. The arching of the axis, or subsiding of the basins on either side, and probably also most of the faults, must have taken place to a large extent prior to the denudation. The Carboniferous rocks of Arthur's Seat were tilted along with the beds on the east of the axis, and now dip eastward below the coal-field. After this tilting the whole of the overlying mass of strata was gradually bared away, along with a large part of the Arthur's Seat beds themselves, the hard greenstones were left protruding as crags, the softer sandstones and shales being hollowed out into valleys, and eventually the hill had, as a whole, very much its present contour, when the eruption of the later rocks began; nay, such may even have been its contour for ages before that period, since the coarse volcanic conglomerate affords good grounds for suspecting that the locality was then, as now, a terrestrial hill. The proof of these assertions is easily obtained. The instructive sections of the Queen's drive, especially that given in fig. 5, show that this conglomerate fills up valleys and wraps round the summits of elevated cliffs. The greenstone bed in that figure must unquestionably have been a prominent crag like Salisbury Craigs when the ash and scoriæ fell thickly around and buried it. The northwest side of the high cliffs near the summit is not less convincing. The ash there fills up the shallow valley between the Long Row and the Dasses, covering over both the crags, and hangs down into the Hunter's Bog, which it once undoubtedly filled, though subsequently removed by a later denudation, for such loose material could not gather as an impending cliff half way up a hill side, but must, even without the impetus of its ejection, have rolled into the valley below.

Now it is plain that, to account for the great changes in the contour of this part of the country from the close of the Carboniferous period to the eruption of the later igneous rocks, we must allow a very long interval. I have already said that there is *nothing* in the district itself to limit the period of the denudation, and to enter into the evidence deducible from other parts of the country would be foreign to the object of the present Memoir. Besides, we are still in want of some important links, especially as regards the Permian of South Scotland, and the question will therefore be more fittingly discussed when a larger amount of collateral evidence has been collected. In the meantime I am disposed to acquiesce in a conjecture of Professor Edward Forbes, that the later rocks of Arthur's Seat are older Tertiary,* or at least that they belong to a late part of the Secondary series.

The structure of the later part of this hill is sufficiently shown in fig. 25. The first ejection was that of the coarse volcanic ash and conglomerate (A), which may be admirably studied all along the Queen's Drive on the south side of the hill. It is an agglomeration of rounded and subangular blocks of all sizes up to 2 or 3 feet in diameter, imbedded in red ferruginous felspathic paste. An examination of the enclosed fragments will show that they consist of the older rocks of the hill, sandstones, greenstones, basalts, porphyries, and armygdaloids. The paste contains abundance of augite crystals. In some places it is soft, granular, and with few stones, again it acquires a firmer consistency, and even occasionally becomes as compact as a greenstone, of which last an instance may be seen on the south side of the hill at the greenstone craig, figured in fig. 5, where the ash is as hard and firm as any of its included blocks. At the south-west corner of the hill, at the cliff called Raven's Craig, the rock passes into a kind of greenstone ash, large fragments of various traps being imbedded in a greenstone base. But the relation of this rock to the rest of the ash is not very clear. When viewed from the south side the main body of ash appears to have a decidedly stratified arrangement, and to dip south-east at about 30°. The sections on the roadway, however, show little trace of stratification. The rock there presents the utmost confusion, and the rude bedding, when any can be detected, dips at all angles and in every direction. The whole aspect of this ash differs so entirely from that of any of the Carboniferous ashes (all of which are undoubtedly subaqueous), and presents so many features indicative of the absence of any assorting agent, that it ought probably to be considered subaerial. If this can be satisfactorily proved, it would form an important step in our inquiries into the post-carboniferous history of Central Scotland. In all future explorations of the hill especial attention should be directed to the bottom of the ash, for it is not impossible that organic remains may be found between it and its carboniferous platform, and these, if well preserved, would probably decide the whole question.

The rock of the summit (B) is a black, very compact basalt, lying in an irregularly oval patch, surrounded on all sides by the ash. It may be traced on the west side, descending into the latter rock, and sending veins into it. In short, it forms what geologists know as a "neck," or plug of solidified lava, filling what was once a volcanic orifice. The reasons for so considering it are well stated by Mr. Maclaren, in his description of the hill ("Geology of Fife and the Lothians," p. 36).*

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* The little sketch-section which Edward Forbes drew of Arthur's Seat, shortly after his return to Edinburgh in 1854, still remains where he placed it, in one of the wall-cases of the Edinburgh College Museum, to illustrate the collection of igneous rocks.

The beautifully columnar basalt (C) of the Lion's Haunch contains large augite crystals with grains of olivine. It differs wholly in texture and structure from that of the summit, and rests upon the ash as an undoubted cake. If the observer will trace its southern boundary, he will find that just above the greenstone in fig. 5 it sends a narrow prolongation downwards, which plunges into the ash. This I am disposed to consider as a lateral orifice, through which the basalt was ejected.

The only remaining rock in the hill is the porphyritic, and occasionally vesicular felstone (D), which forms part of the ridge descending from the summit, and truncating the Dry Dam to the south. Mr. Maclaren considered it one of the carboniferous felstones brought from the east side of the hill by a complication of faults. But there is no evidence of such faults in any other part of the hill, and if they existed, there could not fail to be a trace of them along the well-exposed sections of Salisbury Craigs. Besides, the correspondence in strike between the carboniferous strata on either side of the later unconformable igneous rocks shows that there can be no faults of magnitude in the locality, and that any which do exist more probably throw the rocks east than west. I regard this felstone, therefore, as belonging to the later series of traps, resting on the ash (A), and wrapping round the north-east end of the basalt (C), and as consequently the last of the igneous eruptions in this neighbourhood.

But these later igneous rocks are only the fragments of a once much more extensive group. The coarse ash must have fallen thickly over the site of Edinburgh, and the fact that no trace of its extension now remains is no proof that it did not at one time stretch for many miles over the adjacent country. The cliff of ash above Hunter's Bog is so manifestly a mere fragment, that it only requires to be pointed out. Again, the basalt of the Lion's Haunch never could have stopped abruptly on the surface of such a slope as that of the south side of the hill. Sir Charles Lyell, indeed, has shown† that lavas may consolidate on slopes varying from 15° to 40°, but only at some distance below the orifice, not above it, and along the side of a sharp declivity. It follows, therefore, that the area of Mid-Lothian has to some extent undergone a process of denudation subsequent to the eruption of the later rocks of Arthur's Seat. I do not think that this denudation can be accounted for by the operation of ordinary atmospheric causes, though these may have acted with considerable effect in removing from certain areas the loosely agglomerated dust and scoriæ. But if no other force had been concerned, we should find the ash still remaining in many hollows and other places not exposed to the action of running water. Even on Arthur's Seat there are not a few such sheltered spots, which it can almost be demonstrated were once filled with this later ash, and these certainly could never have been swept out by rains and streams. But we have positive evidence that the district was again submerged after the eruption of these later rocks, and underwent some minor changes of contour. During this period, when hard greenstones and basalts were ground down and polished, the loose ash of Arthur's Seat might well have been swept away, and only that part of it left that had been more firmly compacted round the heated orifice.

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* It will be seen that in this part of the description I agree entirely with that geologist. My explanation of the eastern part of the hill, however, between the summit and Dunsapy, confessedly the most difficult part of the whole, differs altogether from his, and recommends itself, I think, from the simplicity which it introduces into what certainly at first sight seems difficult and confused.

† *Phil. Trans.*, Part II. for 1858, p. 703.

To the traces of this last era of denudation, called the Drift or Glacial period, I shall now advert.

CHAPTER XIV.

DRIFT.—RAISED BEACHES.—RIVER CHANNELS.—LACUSTRINE DEPOSITS.

IN the course of the preceding pages frequent reference has been made to the superficial covering of *drift clay, sand, and gravel* spread more or less over the whole of the district. These deposits belong to the great Glacial Drift which covers Northern Europe, and was formed (during a general submergence of the land) by drift-ice transporting mud and boulders from higher to lower latitudes. The drift of Central Scotland appears to have resulted to a large extent from the action of coast ice, which formed round the shores of the interlacing islands and peninsulas as the land went slowly down. It consists of two main parts: 1st, the Boulder Clay or Till; and 2nd, superficial sands and gravels.

Boulder Clay.—This is a stiff sandy clay more or less characterized by the presence of subangular and rounded stones of all sizes up to several feet in diameter. Its colour here is usually a dull leaden blue or black; its common hue in a carboniferous country. In the Old Red Sandstone district of Berwickshire it is red, and it is known to vary according to the composition of the rocks on which it rests. It lies thickest along the *eastern* slopes of the hills, and never occurs at their summits. It has no determinate stratification, though occasionally sandy partings may be detected in it, and the enclosed boulders have sometimes, though rarely, a rude and apparently accidental semblance of bedding. Even when other members of the Drift series occur, the Boulder clay is not always present, its place being taken by sands or gravels. It occurs, of course, most abundantly on the lower grounds and valleys, except where worked out by the action of streams, but it lies deep on the east side of Cairn-naple Hill, Linlithgowshire, not less than 900 feet above the sea level, and along the north-west flanks of the Pentlands it rises to at least 1,300 feet. No fossils have yet been found in the Boulder Clay of this district, except an ivory tusk at Clifton Hall near Ratho; but the circumstances of its discovery are not satisfactory, and it possibly came out of the remodelled gravels that overlie the blue till.*

When the clay has been recently removed we usually find the rock below polished, grooved, and scratched in a direction nearly east and west or E.S.E. and W.N.W. These markings even remain distinct on hard greenstones which have remained exposed to the weather for an indefinite period. They are familiar to the students of the geological effects of ice, and are found abundantly along the course of glaciers in the Alps, and of coast-ice in other parts of the world. They have been produced by fragments of rock and grains of sand firmly frozen into a mass of ice, the great weight and momentum of which has polished and striated, as with a file, the rocks over which it has passed. The parallelism of the striations throughout the present district shows that the floating ice must have moved in a pretty uniform direction, and that it was from the west, is rendered clear by the striation of the western face of the hills, by the great depth of drift on their eastern side, and by the fact that the transported boulders when traceable to their parent rock have been carried from west to east.

Of the imbedded stones in the Boulder Clay the main mass are referable to the ordinary rocks of the district, greenstones, basalts, sandstones, &c.; but others of mica-schist, gneiss, quartz-rock, and granite indicate a more distant origin. Many of them are striated, often parallel to their longer axis. The majority of the larger blocks are of greenstone, rounded and more or less striated. The peculiar greenstone of Corstorphine Hill can be recognized among the boulders washed out of the clays along the shore east of Leith. Several large blocks of sandstone, probably fragments from Salisbury Craigs, occur in the green hollow between the head of the Dry Dam and the Loch at Dunsapy. Several large greenstone blocks also occur south-east of these; in short, the direction of transport of the boulders has been easterly, but the larger number do not appear to have travelled far. Of those which have undoubtedly been transported either from Cantyre or the Grampian Highlands I may refer to the mass of mica-slate weighing about eight or ten tons on the south-east side of Hare Hill above Habbie's Howe, which was first noticed by Mr. Maclaren. The height of this boulder above the sea is about 1,060 feet. On the other side of the valley on the south-west slope of North Black Hill several smaller masses of white quartz rock occur, fully 1,300 feet above the sea-level.

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* See Bald. Mem. Wern. Soc., vol. iv. p. 58.

Masses of gneiss, mica-slate, and a hard metamorphic conglomerate are found in tolerable abundance all over the district.

The following are typical localities for the study of the Boulder Clay: Silvermine quarry; cutting of Caledonian railway behind Corstorphine Hill; shore at Granton and between Leith and Portobello; clay-pit at Millbank, near Gorebridge; higher part of Dalhousie Burn, near White Hill; and indeed most of the watercourses throughout the district. The glacial scratchings are admirably displayed along the west side of Corstorphine Hill,* where the general direction is rather to the south of west, also near south-east end of Salisbury Craigs, and on side of Queen's Drive above Samson's Ribs; on the side of the railway near Ratho; along the shore near Portobello the pebbles fixed in the Boulder clay are beautifully striated. On Riccarton Hill, west of Currie, the striations have a bearing of W. or W. 10° S.; on the limestone at Silvermine, W. 10° N.; on the sandstone of Hillhouse, due west; every removal of the superficial drift usually shows a striated surface on the rocks below.

The peculiar contour of the hills called "Crag and Tail" was partly at least produced during the Drift period. Many of the more prominent hills consist of a narrow ridge sloping gently towards the east and rising abruptly from the lower ground on the west side. They also commonly have a valley or depression immediately below the steep side. The prominent part consists of hard trap-rock, and the tailing declivity of sandstones and shales. "Crag and Tail" is well displayed by the Castle Rock, Edinburgh, by Arthur's Seat, and Calton Hill. But perhaps the most striking example in the whole of the district is that of Binny Craig. The summit is 718 feet above the sea, and 120 feet above the hollow on the west side, from which it rises precipitously into the most conspicuous hill between Edinburgh and Stirling. It is supposed that drift-ice driven from the west against these abrupt crags ground them down and heaped up mud, sand, gravel, and boulders on the east or lee-side. But this seems to account merely for the later modification of the outline of these hills, which must have been prominent before the beginning of the drift; ice-action would tend to abrade existing ridges by making them narrower and lower, but it would hardly denude a country into ridges each bounded on the west by a trap-hill. It seems necessary, therefore, to refer the main features of "Crag and Tail" to a previous period, and to some process at present not easily explained.

The character of the Drift in this district indicates a period of slow submergence, which went on until probably every hill had sunk far below the sea-level, and when ice-borne blocks, from the snow-covered islets of Isla or the Grampians, were dropped on the submarine slopes of the Pentlands. When the land began to rise again, the successive levels of drifted material brought up to the sea margin would undergo a process of sorting and re-arrangement. Hence arose the sands, gravels, and stratified sandy clays which cover the great blue *till*. They may be seen everywhere. I may refer especially, however, to some parts of the valley between Linlithgow and Falkirk, and also to the lime quarries of Crichton Dean. These superficial deposits have of course a general stratified arrangement, often rude enough, however, and even wanting. In some parts, as for instance, in the sand pits half way between Edinburgh and Portobello, the sands are perfectly stratified with that diagonal lamination, or false bedding, so common in the carboniferous sandstones of these counties.

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* See Sir James Hall's Paper, Trans. Roy. Soc. Edin., vol. vii.; also Maclaren, Geol. *Fife and Loth.*, p. 214; Fleming's Lithology of Edinburgh, p. 34.

Brick-clays.—Care must be taken not to confound the sands last mentioned with others of a still later date, formed in great measure by a washing of the Drift along the corners of streams. The peculiar loose shingly character of such river deposits can in general be sufficiently discriminated. The observer must also guard against classing together the blue till or boulder clay with certain fine stratified clays, containing few or no pebbles and used for brickmaking. Such *brick-clays* are well displayed in the tile works at Portobello, where they contain *Scrobicularia piperata*, nuts of the hazel, and branches of oak, beech, thorn, hazel, &c. all of still indigenous species, while the boulder clay has not yet proved fossiliferous. The true brick-clays* only occur in the present district along the coast line, as at Portobello, Granton, and Blackness. They are evidently the result of a washing of the underlying boulder clay, when the land stood from 20 to 50 feet lower than it does at present. Such a difference of level would indent the southern shores of the Forth with little creeks and inlets, where the sea washing against bluffs of the boulder clay would re-arrange its materials, leaving the courser parts as sand and shingle along the shore, and depositing the finer mud in stiller water to seaward. Where any stream entered it might carry logs of wood from the interior, and these would readily be entombed in the muddy silt. Such appears to have been the origin of the brick-clay of Portobello.

Raised Beaches.—The brick clays, therefore, must be connected with a rising of the land subsequent to the general elevation at the close of the glacial epoch. The proofs of this change of level are numerous and satisfactory, and occur more or less along the whole southern coast line of the Firth of Forth. They are well exhibited on the road between Leith and Portobello. There the boulder clay forms the present beach, and along the high-water line, where far out of the habitat of the living shells, it is perforated by *Mya truncata*, with the siphuncular end uppermost, and other shells in their natural position. Dr. Fleming, in his Lithology of Edinburgh, has endeavoured to throw discredit on Hugh Miller's observations at this locality. I visited the beach with the latter naturalist after his paper* had been written, and we collected twelve additional instances of the *Mya truncata* in its natural position. His observations are certainly worthy of the fullest confidence, they show that at a former period what at present forms the high-water line must have lain within the habitat of the *Mya*, that is between 18 and 40 feet lower than at present.† But this locality affords additional evidence of a rise of the land. Immediately above the boulder clay with the *Myas* there is a low cliff made up of successive strata of sand and shells of the common littoral species. The assortment of these beds could not have been effected by wind; they are undoubtedly the products of wave-action along a sandy shore, and they therefore represent a former line of beach. But, further, if we cross the level space formed by the grass grown surface of these strata we come to a wavy indented cliff line of boulder clay. This must have resulted from the eroding influence of shore-waves; there is no other way of accounting for it; it was in fact the high-water mark at a former period of our country's history, when the land stood perhaps from 30 to 40 feet lower than it does to-day. We have here three sources of corroborative evidence, the shells, the littoral sands, and the receding indented cliff-line.‡

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* The term is used in a geological, not an industrial sense. Some parts of the boulder clay, where free from boulders, are in many parts used for brickmaking. The term *brick-clays*, however, is generally used by geologists in Scotland to denote those fine stratified *re-formations of the boulder clay* containing organisms of species still living in the neighbourhood.

Similar features can be traced westward by Granton to Queensferry, and thence to the mouth of the Avon. At Kinneil a long bed of detached oyster valves, lying with great regularity among sandy beds, occurs about 36 or 38 feet above high-water mark, and is flanked behind by a steep cliff-line, the top of which averages about 90 or 100 feet above the high-water line.§

Alluvium, River Deposits.—As the present valleys in which the streams flow are usually more or less filled with drift, they must be assigned to a period anterior to the drift, save in those cases where it can be shown that they have resulted from glacial action. Most probably, before the glacial submergence, they were traversed by streams as now, so that, since the re-elevation of the land, the work of these streams has, in many cases, only been to sweep out the drift and deepen their former channels. The inequalities of the surface of the drift, however, would doubtless give rise to many new watercourses, which would retain their direction in the solid rock even after the superficial drift had been removed.

The alluvial deposits and the eroding power of streams may be advantageously studied in the higher reaches of the Water of

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* Hugh Miller's paper on this locality was read before the Royal Physical Society of Edinburgh, but not published.

† The *Mya truncata* occurs in the Firth of Forth from low water to seven fathoms.

‡ The significance of such facts as those on which the above inferences are founded was first pointed out more than 20 years ago by Mr. Smith of Jordanhill, Edin. New Phil. Journal, xxv., p. 378.

§ Maclaren, Proc. Roy. Soc. Edin., vol. ii. p. 365.

Leith. There is a particularly instructive part of its course at Leith Head Mill, in the parish of Kirknewton, where the stream has left two terraces above its present bed, the under one being from 3 to 4, and the upper 8 to 10 feet above the level of the stream. The whole course of this stream is full of instructive sections, not only of the older rocks, but of the drift and of the action of streams liable to sudden freshets. In the sections of its alluvial deposits layers of dark peaty matter are often seen interstratified among its sandy beds, indicative of former surfaces of vegetation destroyed by irruptions of silt when the stream was in flood. Such interlaminations never occur among the superficial sands and gravels belonging to the drift series. River deposits have commonly a looser, more shingly character than these drift beds, and of course occur in valleys or low grounds where streams could act, and not on the sloping sides of hills, as the latter often do.

The extensive flats of mud and silt along the shores of the Firth, more especially on the south side, are due to the detrital matter brought down by the Forth, and deposited when the onward motion of the fresh water is checked by the contrary direction of the tides. Some of these alluvial plains have been reclaimed, as the Carse of Kinneil and others might be, especially between the coal-fields of Borrowstounness on the south side of the estuary and Torryburn on the north, the subterranean mineral wealth compensating in this case for the expense, in addition to the great agricultural value of the alluvial soil.

Lacustrine Deposits.—In the district described in this Memoir there are three natural lakes,—Linlithgow, Lochend, and Duddingstone Lochs, besides evidences of several others. The deposits of a lake consist of peaty matter, fine sand or mud, and layers of marl formed of the congregated remains of *Paludina, Lymnea, Planorbis,* and other fresh-water shells. These shells are found living in the lochs just named, as well as in ponds and ditches in the neighbourhood, and layers of vegetable matter are also gathering, especially along the margin of the water. Duddingstone Loch is in this way slowly becoming filled up by a growth of aquatic plants. The Meadows, Edinburgh, once formed a lake called the Borough Loch; and a painting still exists of Watson's Hospital from the south, showing the strip of blue water of the Borough Loch in the foreground. In the process of sinking some drains in this locality, a bed of lake-peat, from a few inches to upwards of a foot in thickness, was found immediately below the soil. A thin layer of marl, with the common fresh-water shells, underlaid the peat and rested on some silt sand or fine gravel, below which came the boulder-clay.*

Similar evidence exists at Linlithgow of the lake there having once covered a much more extensive area.

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* Fleming's Lithology of Edinburgh, p. 102.

Blown Sand.—The "links" of Musselburgh and Leith are dunes of blown sand, the movements of which have beenarrested by vegetation.

For the geological effects of still active forces, the observer should examine the whole coast line, noting the various modes in which rocks yield to the action of the surf, and the way in which the sediment thus produced is assorted above low-water mark. With this he will connect the habitats of Mollusca, &c., as these bear on geological speculation. The ravines will furnish him with proofs of the agency of frosts and rains, and the powerful though tardy influence of streams. The lakes and ponds offer to him interesting facilities for comparison with some of the older rocks described in this paper. By thus connecting the present with the past conditions of the country he will acquire a more enlarged and a more thorough knowledge of both.

A. G.

NOTE TO p. 129.

Since the preceding pages were printed a remarkable section has been laid open in the raised beach of the south side of the Firth of Forth. It occurs on the side of the Junction Road which skirts the southern edge of the town of Leith, and lies above the valley of the Water of Leith at a height of about 25 feet above the present high-water mark. The following is the succession of beds there visible :—

1. Littoral sand, broken shells and stones, with barnacles affixed.
2. Brown sand, earthy below, passing down into
3. Dark sandy clay with *ostrea*, *mytilus*, and pieces of pottery. Thin lenticular seams of sand are interstratified.
4. Thin seam of sand and gravel.
5. White sand showing diagonal stratification.
6. Coarse shingle.

The bed marked No. 3 was examined by me with great care, and I ascertained beyond the possibility of doubt that it is a true littoral deposit, formed exactly as similar dark muddy silt is now forming along the shores of the Firth. It presents every evidence of quiet deposition, and is moreover covered by successive layers of sand and gravel, some of the larger stones having still their barnacles attached. The pottery fragments are imbedded in this clay horizontally like the flat stones and oyster valves. They are thick, of a coarse texture, and pale yellowish grey colour, and exactly correspond to fragments of undoubted Roman pottery in the Scottish Antiquarian Museum. The inference to be drawn from their occurrence here is that the land along this part of the Firth of Forth has risen 25 feet, or thereabouts, since the time of the Romans. A detailed account of the section, with notices of the Roman walls, ports, and other remains along the sea-margin of this part of Scotland is in preparation, and will be published elsewhere.—A. G.

APPENDIX.

DESCRIPTIONS AND LISTS OF FOSSILS, BY J. W. SALTER, F.G.S.

NOTES on the SILURIAN FOSSILS of the PENTLAND HILLS.

The relations of the Silurian beds of the Pentland Hills could not be satisfactorily made out, till the Lesmahago district in Lanarkshire had been examined for fossil data. They were accordingly compared in the summer of 1859, and the following succession established, which is nearly identical for both districts :—

1. *Dark thin bedded Shales*, with Crustacea (*Ceratiocaris*), at Lesmahago. Possibly the same beds at Habbie's Howe, Pentlands, with no fossils. These lie at the base of the section. Above them come—
2. *Hard stone-bands*, with olive shales between them, Logan Water, &c., Lesmahago, North Esk Reservoir, and Bavelaw Castle, Pentland Hills. These bands are full of a peculiar crustacean, *Dictyocaris*.
3. *Pterygotus shales*, dark blue grey (with many Crustacea in the Lesmahago district). Of much more varied composition in the Pentlands, and fossils very scarce in the latter.
4. *Lingula* and "*Trochus*" *beds*.—So called from the great abundance of a small *Lingula* and a spiral shell allied to the *Trochus ? helicites* of the Upper Ludlow Rock. The spiral shell only is present in the Pentland Hills, but is associated with numerous species not found at Lesmahago. In both cases these beds pass up into—
5. *Red Sandstones and Shales*.—Base of the Devonian Rocks. The above sketch is given for the sake of definitely establishing the claim of the Pentland rocks to be considered (as those of Lesmahago certainly are) the uppermost beds of the Silurian series, or Ludlow Rocks. They were formerly, on the evidence of one or two fossils, considered as Wenlock.

There is sufficient diversity, however, both of mineral character and fossils, between the two districts, to warrant the belief that they were under different conditions of depth of water at equal times. The rocks of the Pentlands were less argillaceous, and more varied in composition during the deposition of the *Pterygotus* shales, No. 3, than those of Lesmahago ; and they consisted of finer sediment, with only occasional grit-bands, in No. 4. These last-mentioned beds, which are not uniform in texture, and contain but very few fossils at Lesmahago, have in the Pentlands a great number of species,—shells, sponges, crustacea, and echinoderms, as shown in the following lists.

No. 1. Beginning with the lowest beds, the dark shales have as yet yielded nothing, but are very well worth further search for *Graptolites at Habbie's Howe.*

No. 2. *Stone bands and olive shales,* contain

Graptolithus priodon, Hare Hill, Pl. II., fig. 22.

Rhynchonella compressa, Hare Hill and North Esk Reservoir.

Theca, sp., Pl. II., fig. 21.

The above species were discovered by Mr. Geikie.

The most abundant fossil, however, is a large new crustacean described by me in the Annals of Natural History for March 1860, and named *Dictyocaris,* on account of the coarse reticular surface. It is apparently a huge Phyllopod, distantly allied to *Apus* or *Nebalia.* Only the carapace (which is bent along the dorsal line, not bivalved,) and an obscure body ring or two, are yet known, but it is so conspicuous and common a fossil that it must receive a name. Fragments of it occur everywhere in the Lesmahago district, and in similar beds.

Dictyocaris, n.g.

Carapace ample, triangular, pointed anteriorly, the posterior margin truncated, the ventral edge produced (truncate?) and strongly margined. Surface covered with a close hexagonal reticulation. Body joints and caudal appendages ?

Dictyocaris Ramsayi, n. sp., Pl. II., fig. 20.*

D. modicus, testâ solidulâ ? Cephalothorax 4 *uncialis, triangulatus, posticè convexus, ferè gibbus; dorso rotundato, margine ventrali producto truncato, valde marginato.*

I cannot but believe this a distinct species from the *D. Slimoni* of Lesmahago, with a much more triangular carapace, thickened, and margined by a tolerably strong furrow along the anterior and ventral margins. Moreover, the carapace appears to have been far more convex, less distinctly reticulate, and never to have attained the size of *D. Slimoni,* which is often 7 inches diameter. (Ann. Nat. Hist. l.c. 1860, p. 162.)†

A strong ridge must have existed on the inner side of the carapace along the ventral border, as a furrow is left there on the cast, and several irregular ridges run along the dorsal margin, or down the posterior slope, due probably to grooves on the inner surface. In our figure the anterior portion is restored in outline. A corresponding fragment shows these grooves strong and definite upon it.

Locality.—North Esk Reservoir, south-east end of the Silurian patch near Carlops.

No. 3. Has yet yielded no fossils in the Pentland section.

No. 4. Upper Ludlow Beds; the "*Trochus*" beds of Lesmahago; commence with a grit bed (with some traces of fish?), then followed by a light coloured shale full of fossils.

The following is a list of the species. The numbers of the quarries are given in ascending order, but there appears to be little difference between them. *b.* is the lowest shale quarry above the fish bed *a.*

b. *Chondrites verisimilis,* n. sp., a true seaweed, Pl. II., fig. 1, 2.

b. *Amphispongia oblonga,* n. sp., Pl. II., fig. 3.

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* The author of the "Gentle Shepherd" laid the scene of his poem in this district.

† I think the restoration of the body there given might be improved by thickening and enlarging it, and I have done so in our figure 20 *a.*

b. *Stenopora fibrosa*, Goldf.
b. *Favosites alveolaris*, Goldf.
b. *Petraia*, sp.
c. *Protaster Sedgwicki*, Forbes ; a Kendal species, Pl. II. fig. 4.
a. *Periechocrinus*, and two other kinds of Encrinite stems.
b. *Serpulites*, sp.
b. *Beyrichia Klödeni*, McCoy, var., fig. 5.
b. *Phacops Stokesii*, M. Edw.
c. *Encrinurus*, sp. new.
b. *Pterygotus acuminatus*, Salter,—a fine jaw-foot of this species.
b. *Ceriopora granulosa*, Goldf., Pl. II. fig. 6.
c. *Rhynchonella*, distinct from *R. Wilsoni*,—fig. 7.
a, *b*. *Atrypa reticularis*, Linn.
b. *Orthis elegantula*, Dalm.
b ? *O. reversa*, Salter ? or an allied species (p. 138.)
b. *Strophomena applanata*, Salter.
b. *S. depressa*, Dalm.
b. *Leptæna transversalis*, Dalm. (in quantity), fig. 8, 9.
b. *Lunulacardium elegans*, n. sp., fig. 10.
b. *Ctenodonta obesa*, n. sp., fig. 11, 12.
b. *C. Thracioides*, n. sp., fig. 13.
b. *C.*, small smooth oval species.
b. *Anodontopsis lucina*, n. sp., fig. 14.
b. *Orthonota bulla*, n. sp., fig. 15.
b. *O. amygdalina*, Sow., var., *gentilis*, fig. 16.
b. *Loxonema*, sp.
c ? *Euomphalus funatus*, Sow.
b. *Acroculia antiquata*, fig. 17.
b. do., young, or another species ? fig. 18.
b. *Cyclonema*, n. sp.
b. *Pleurotomaria*, sp.
a, *c*. *Platyschisma simulans*, n. sp., fig. 19.
c. *Bellerophon* (like *B. carinatus*), Sow.
b. *Orthoceras McLareni*, Salter.
b. *O.*, smooth species.
c. *O. subundulatum*, Portl.
b. *Conularia Sowerbyi*, Defrance.
b. *C.*, sp.

Descriptions of the Species.

ALGÆ.

Chondrites verisimilis, Pl. II., fig. 1, 2.

Frond two or three inches long, bipinnate, much branched; the branches fastigiate but not crowded at the tips, wavy or even zigzag above, and clothed with frequent short setaceous ramuli. The branches are linear, narrow below, alternate, branched again from their lower portions, and as well as the upper branches at an acute angle. The ramuli are curved, oblique near the ends of the branches, but more spreading below ; apparently they are in distichous arrangement,—never secund.

The above description, though necessarily imperfect, will recal several of the common British species of *Algæ*. There is the bipinnate frond, with flat or compressed branches, collected into somewhat fastigiate or bushy tops, and beset with short pointed ramuli, as well as the zigzag form of the branches themselves, which are attenuated below, and generally alternate, but sometimes accidentally opposite. Nearly all that could be said of a British specimen of *Gelidium cartilagineum* or *Plocamium coccineum* might be said of this old species. This is the more satisfactory, because scarcely any of the so-called *Fucoids* of the old rocks are truly so, the branched and inosculating burrows of marine worms having been in so many cases mistaken for them. Of this one there can be no doubt. Three specimens were found in a limited space.

Locality.—Deerhope, Pentlands, on the North Esk Reservoir, above Carlops, Peeblesshire ; collected by Mr. R. Gibbs.

AMORPHOZOA.

Amphispongia, n. g.

A calcareous sponge, of oblong or subclavate shape, and upright growth, solid, or with a narrow central vertical canal below, from which branch off numerous oblique, strong-walled, lateral tubes, the interstices crowded with spicula. Above, the mass is wider, apparently with a large cavity (so as to become pressed flat in the fossil) and with no distinct canals but abundant spicula. These latter are large, apparently tricuspid (T shaped*) with a bulb at the point of trifurcation, and their longer sides arranged transversely, and nearly parallel, over the surface. The apparent difference of structure in the upper and lower portions suggests the name.

A. oblonga, n. sp., Pl. II., fig, 3.

Numerous specimens of this irregular fossil were found in a small quarry above the North Esk Reservoir on the Pentland Hills.

They appear as compressed elongate, oblong masses, about 1½ inch long, and ½ of that breadth above. Below they are considerably narrower, and with a blunt rounded base, the general shape being thus somewhat clavate. The lower portion,—about one sixth,—which must have been more solid than the upper, is conspicuously different from it ; numerous curved radiating bars (hollows in the cast) rise obliquely from the central line, and terminate bluntly with rounded tips on the periphery. Above these, similar but longer, narrower, and straighter radiating bundles occupy the middle of the mass, and between and among these and the more solid masses before mentioned, numerous fine slender spicula are closely packed. The upper and wider portion is occupied by these small spicula only, which are seen under a glass to be triradiate, with one cusp at right angles to the two others, and bulbous at the point of insertion. They are arranged transversely to the axis, with the straight sides outermost, and the third cusp directed inwards, and are placed so closely in transverse lines parallel to each other, as nearly to cover the surface. From their leaving cavities in decay, they must have been calcareous, not siliceous ; and the radiating bundles have the same character, and are almost certainly the places of close packed groups of spicula which formed the walls of radiating canals like those of *Grantia*. These strong bundles only occur near the base.

In all this there is a general agreement with those calcareous sponges described by Dr. Bowerbank, of which the nearest type to the fossil appears to be the species of *Grantia*. There is a central cavity, largest above and contracted below into a mere canal by the thickening of the parietes of the sponge, and a consequent elongation of the lateral (interstitial) canals in the lower part. A skeleton of triradiate rectangular spicula, combined with bundles of long needle-shaped (acerate) ones around the larger apertures, and a general similarity of form. All these characters combine to assimilate *Amphispongia* to *Grantia* from which however the apparent absence of lateral canals in the upper part, and at all events the great solidity of their walls in the lower part, will distinguish it readily.

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* Rectangular-triradiate (Dr. Bowerbank) is perhaps a better term. See his paper on *Grantia* in Trans. Micr. Soc. vol. vii. pl. 5. In a letter (1861) he says, "*Amphispongia* " has characters of close alliance with *Grantia ciliata*, &c., in the arrangement of " the large intermarginal cells, &c. The rectangular-triradiate spicula should be near " the apex. Have you no equiangular ones in the parietes?"

This is not the first determination of sponge spicula in Silurian rocks. McCoy has described some very large 4-or 5-rayed spicula in his "Synopsis of the Silurian Fossils of Ireland," p. 67, and provisionally named the genus *Acanthospongia*. There seems no reason to doubt the correctness of this supposition, notwithstanding the great size of the spicula, and the want of definite shape in the mass.

But the number of Silurian sponges is much more extensive than we have yet supposed. *Stromatopora* is the only genus generally admitted from these rocks. But a late examination of some Upper and Lower Silurian fossils of that convenient group "*Incertæ sedis*" has shown me, 1st, a sponge quite closely related to the genus *Dunstervillia* of Dr. Bowerbank, in the Caradoc strata. He had long ago, in his paper on the recent sponge,* shown that the great *Sphæronites pomum* from the Devonian Rocks† was a sponge allied to the *Grantia*, and with his permission I propose now the term *Sphærospongia* for the Devonian species. The Caradoc fossil is of the same genus.

Ischadites of König is a more regularly formed sponge, with vertical and transverse bundles of fibres. I have lately seen the rootlike attachments. A fossil figured by McCoy in the synopsis of the Woodwardian fossils, and which is very common in the Kendal Rocks, I hope shortly to describe with others under the name of *Favospongia Ruthveni*.‡ The *Tetragonis Danbyi* of the same author is one of the same family; and several Russian species of these or kindred genera have been figured by Eichwald in his new Fasciculi of the *Lethæa Rossica*. Lastly, while I write, Professor Ferdinand Rœmer has published a fine series of sponges of various forms from the Upper Silurian Rocks of Texas.§ There is not space here to do more than indicate the class to which these bodies belong. Lastly, though I have myself published it as a great Foraminifer, I believe *Receptaculites*|| will prove to be a very regular cup-shaped sponge, with its skeleton arranged precisely after the pattern of the soft parts in the *Orbitolites*, and hence illustrating the close connexion between the *Spongiadæ* and the *Foraminifera*.

Protaster Sedgwicki, Forbes ?

Ref. Forbes, in Decades, Geol. Survey, pl. I.

The specimen is so imperfect that it cannot be said with certainty to belong to the above-named species, but it is quite as much like it as the Ludlow species *P. leptosoma*, and, being a northern form, more probably identical with the Westmoreland fossil.

I may mention here that *Protaster* is also a Lower Silurian genus, the so-called *Ophiura Salteri* of Professor Sedgwick's lists (from North Wales) proving to be of this genus. It is also, I think, without much doubt equivalent to *Tæniaster*, Billings, from Lower Silurian Rocks in Canada. And lastly, it must be referred to the *Asteriadæ* proper,

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* Ann. Nat. Hist., vol. xv. p. 299. † Phillips, Cal. Foss. Cornwall, &c., pl. 59.

‡ Pal. Foss. Woodw. Mus. pl. 1D, f. 9. *Tetrag. Danbyi*, ib. f. 8.

§ Silurische Fauna des Westl. Tennessee. Breslau, 1860.

|| Mem. Geol. Surv. Canada, Organic Rem. Decade 1, pl. 10.

owever much its form imitates that of the *Ophiuræ*, for it has lately een found to have the usual madreporic plate on the disk. There is o living Asteridan with so extreme a form.

*Entomis.** (T. R. Jones).

Mr. Jones furnishes the following description :—

A bivalved Entomostracan, having an almond-shaped compressed carapace. Valves strongly indented by a transverse furrow, which begins on the dorsal margin, at about one-third of its length from the anterior extremity (the usual place of the dorsal notch in *Leperditia* and *Beyrichia*), and extends in some cases to the ventral border. Surface smooth (?), presenting sometimes a rounded tubercle in front of the sulcus.

Entomis has the carapace more oval, and more compressed than *Leperditia* and *Beyrichia*. It is larger than the latter ; and appears to have had thinner valves than either genus.

Entomis tuberosa, T. R. J., sp. nov., Pl. II. fig. 5.

We obtain the following characters from—1st, the artificial cast of an impression made by a pair of distorted valves in a light brown mudstone from the Pentland Hills (taking the longer valve as having suffered the least alteration of form) ; 2nd, a somewhat better preserved cast, in a light greenish grey, fine-grained calcareous rock from Bow Bridge, Ludlow, Shropshire.

Valves suboval ; in one specimen $\frac{3}{16}$ths inch long, and $\frac{2}{16}$ths inch wide, in another (from Bow Bridge) $\frac{1}{4}$ inch long, and $\frac{1}{6}$ inch wide. Dorsal margin nearly straight in the middle third, and curving off rapidly at the ends. Ventral margin rounded, most convex in the posterior third. Extremities rounded, the anterior narrowest.

The transverse sulcus is strongly marked, curving forwards, and indenting nearly three-fourths of the width of the valve. Anterior to the furrow, and within its curve, the surface of the valve is raised up into a round tubercle.

In the specimen from Bow Bridge there is no clear trace of the tubercle, which has disappeared owing to pressure.

E. tuberosa occurs also in the Upper Ludlow Rocks at Aymestry, and in the Silurian Rocks of Australia. In another smaller species (*E. divisa*) MSS., from the neighbourhood of Builth (Upper Silurian), the sulcus extends quite across the valves, and there is no tubercle.

Pterygotus (*Slimonia*) *acuminatus*, Salter.

Ref. Quart. Geol. Journal, vol. xii, pl. 29, fig. 4 ; Monographs of British Fossils ; I., pl. 2.

Only the serrate base of one of the great swimming feet has occurred to Mr. Gibbs' diligent search ; but this is invaluable, as tending to connect the beds in which it is found with those of Lesmahago.

It is a remarkable thing, that the species of this group should have so restricted a range, while the trilobites have so large a one. Not one of the Scottish species, either Upper Silurian or Devonian, occurs in the Shropshire district, although the vertical range of a species in each case was considerable.

Locality.—Deerhope (Lower quarry *b*).

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* From ἐντομίς, an incision.

Ceriopora granulosa, Goldf., Pl. II. fig. 6, nat. size and magnified.

Ref. Goldf. Petref. t. 64, f. 13 ? Lonsdale, Siluria, 2nd ed., pl. 41, f. 29.

This species (at least the one that is figured for it by Lonsdale) has a tortuous stem, and appears to have much deeper cells, with more prominent edges. This may be partly due to wear. I do not like to separate the two forms. Both have elongated stems, 2 inches at least, and not more than $\frac{1}{30}$th of an inch thick.
Locality.—Lower quarry, Deerhope (*b*).

Rhynchonella, . . . sp.

This is figured to show a very abundant fossil in some of the Pentland Hill strata. It is too imperfect to identify with published forms. But in its narrow shape it is allied to *R. angustifrons*, from which the striæ distinguish it, and from *R. Wilsoni* the shape separates it.
Locality.—Deerhope (in bed *c*).

Leptæna transversalis, Dalm., Pl. II. figs. 8, 9.

Ref. Siluria, 2nd ed., pl. ix. fig. 17, Pl. xx. fig. 17.

Fig. 8 is a cast of the outside of the smaller or concave (dorsal) valve, and shows the strong ribs and faint intermediate striæ characteristic of this species. The other valve has only the stronger ribs at all distinct. In *L. sericea*, on the other hand, the ribs are less prominent, and the fine striæ conspicuous in both valves. The shape of *L. transversalis* is more triangular, and less transverse than in *Leptæna sericea*, but there is not much difference in the internal structure (fig. 9) of young specimens, except that *L. transversalis* has sharp strong interior spines which roughen the whole inner surface, leaving holes like pin-holes in the cast. Older specimens differ more widely in the muscular impressions.
Locality.—Deerhope (*b*).

Orthis . . . sp.

O. reversa, Salter in Griffiths, Synops. Silurian Fossils, pl. v. fig. 2 ?

There is an *Orthis*, an inch wide, in these rocks, which at first sight looks like the common *Orthis resupinata* of the Carboniferous strata, but on a closer examination it appears to have considerable differences. The striæ are very numerous, the hinge line short, the upper valve convex, and the ventral valve depressed near the margin. It is like a magnified *Orthis reversa*, but can hardly be the same species. Want of space compels me to omit a figure of it, and I do not think it right to describe a new *Orthis* without a figure.
Locality.—Deerhope.

Strophomena applanata, Salter.

Mem. Geol. Survey, vol. ii. part 1, pl. xxvii, figs. 1, 2.

A small flat species,—which is so like *S. pecten*,—that it may easily be mistaken for the young of it. The ends of the ribs project beyond the margin of the shell, which is flatter than it is in the true *S. pecten.*
Locality.—Deerhope (*b*).

Lunulacardium elegans, Pl. II. fig. 10.

L. semiuncialis et ultra, subtrigonum, convexum, per totum radiato-striatum, latere postico haud valde angulato nec elongato, latere antico producto angusto. Umbo subcentralis. Striæ medianæ latiores. Lineæ incrementi irregulares, distinctæ.

I am compelled to adopt Munster's very imperfectly defined genus. It appears to include a number of thin hingeless shells, with a shape and sculpture much like *Cardium*, to which in all probability they are nowise allied. It is probably nearer to *Cardiola*. The genus seems a necessary one to include many Silurian forms. They have always prominent anterior (rarely subcentral) beaks, a carina down the posterior slope, and a more or less evident lunette anteriorly. The shell is very thin.

The genus is Upper Devonian, according to Münster. The Silurian species we refer to are both Lower and Upper Silurian—chiefly the latter.

There are several unpublished forms in the Upper Silurian Rocks; but the one nearest to ours is a species with finer striæ, a much more lateral beak overhanging the anterior third, an angularity proceeding vertically from the beak to the front margin; and *no* lines of growth visible.*

The subcentral beak, rather coarse central striæ (the remainder cover the whole surface), and strong irregular lines of growth distinguish this species easily.

Locality.—With the last (in *b*).

Orthonota amygdalina, var. *gentilis*, Pl. II. fig. 16.

SYNONYM, *O. amygdalina*, Sow., sp., Siluria, 2nd ed., pl. xxiii. fig. 6.—VAR. *gentilis*. Lunette very shallow; anterior side rather prominent.

Except that the lunette is smaller, and the anterior side less truncated than usual, I see little that would distinguish readily this form from the common Ludlow varieties. But then the differences in these particular points are very strong and striking; the lunette is scarcely indented, and the anterior side is prominent for the species. It is true some specimens of *Orthonota amygdalina* have not the anterior flattening, but these have a very deep lunette. Others, with a shallow lunette, have the anterior side much flattened and reduced in size. I propose to call it only a variety, but there are some reasons for believing the whole of this Upper Ludlow fauna in Scotland to be representative of the English one, not identical with it.

Locality.—Deerhope (quarry 3.)

Orthonota bulla, n. sp., Plate II. fig. 15.

O. lævis (nisi lineis incrementi rugisque nonnullis ornata) transversa, inflata. Latus anticum angustum productum rugatum, et â sulco fere verticali sejunctum. Nates haud prominulæ. Lunula modica, ut supina. Long. $\frac{11}{10}$ unc.; lat. $\frac{5}{10}$; alt. valv. amb., $\frac{6}{10}$.

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* I subjoin a diagnosis, as the species is a common one in cabinets :—

L. aliforme, *Semiunciale et ultra, convexum, obliquum, per totum striatissimum, latere postico perangulato, producto; antico brevi rotundato. Umbo valde excentricus, subcarinatus anticam tertiam impendens. Superficies striis radiantibus (medianis vix fortioribus) lineis incrementi nullis, ornata.*

Locality.—Wenlock Shale, Bishop's Castle: Lower Ludlow, Vinnal Hill, &c., Ludlow.

O. bulla differs from the *Cypricardia undata* of the Silurian system, to which it is closely allied,—1st, in the more transverse, and greatly more inflated form ; 2nd, the produced anterior side, the lunette facing upwards, and not inwards ; 3rd, the furrow dividing the anterior side from the disk falls more beneath the beak in the left valve, and so cuts off a smaller portion, which has coarse rugæ (5 or 6) not crossing over the furrow to the disk, except in quite the young shell.

In *O.* (*Cypric.*) *undata* these rugæ are less coarse, more numerous (12 at least), and run out beyond the furrow upon the disk itself.

Locality.—With the last.

Orthonota . . . sp.

Species brevis subquadrata, semirugosa.

A short, squarish species, occurring with *O. bulla*, but which we have not room to figure. The ribs are more like those of *O. undata* (Siluria, 2d ed.), but the shell is no longer than broad.

Locality.—With the last.

Orthonota . . . sp.

Species transversa, oblonga, postice truncata.

A fine species, an inch and a half wide, with a gentle convexity (bluntly angulated) along the siphonal ridge, a truncate posterior margin, and a remarkably straight hinge line. It would have been worthy a name, had we space to figure it. But the Silurian fauna of the Pentlands must receive further illustration. And this short notice will perhaps stimulate collectors in what will most surely be a very prolific field.

Locality.—Deerhope, in the fish (?) bed quarry (*a*).

Anodontopsis (?) *lucina*, n. sp., Pl. II. fig. 14.

A. orbiculari-quadrata, compressa, quam longa paullo latior, antice et postice truncata, nate subcentrali arcuata ; e quo carinæ duæ, postica angulata marginem ventralem attingens, antica obsoletior. Superficies rugis concentricis crebris lineisque radiatis nonnullis ornata. Long. 7 lin.

The genus *Anodontopsis* is a very doubtful one, yet Professor McCoy did well to propose it for a number of obscure Upper Silurian forms allied to *Modiola*, but with very thin shells and a suborbicular shape. He has published one of the smaller rounded forms, besides his typical species, and a few have been described by myself (Mem. Geol. Survey, vol. ii., part 1, pl. xx.) They are the only ones that need be compared with *A. lucina.* The *A. bulla* (McCoy, Pal. Foss., Woodw. Mus. pl. I., k, fig. 11) is a rounded species, with only the ordinary lines of growth. But *A. quadratus*, mihi (l. c.), is a good deal like *A. lucina* in shape. It has, however, neither the concentric rugose striæ, nor the two carinæ radiating from the beak.

The concentric ridges are too strong for striæ, yet not regular enough to be called ribs. Besides the carinæ on the posterior ridge, and the shorter one marking off the anterior slope, there is an obscure radiation over part of the surface which I have not seen in other species. The beak is placed rather nearer to the posterior than the anterior side, but curves decidedly towards the latter.

Locality.—Deerhope (in *b*).

Ctenodonta obesa, n. sp., Pl. II. figs. 11, 12.

C. semiuncialis, transversa, ovata, inflata, sublævis, latere postico brevissimo subacuto, nec carinâ sejuncto. Margo ventralis convexus, vix sinuatus. Nates depressi curvi.

A pretty species, easily recognized, even in this numerous genus, by its inflated form and depressed curved beaks. The surface has rather strong lines of growth, but no ridges or ribs. The posterior side is excessively short, yet its form is somewhat projecting (see fig. 12), and the ridge which separates it from the disk is blunt, and cannot be called a carina.

Locality.—Deerhope Rig (in *b*).

Ctenodonta Thracioides, n. sp., Pl. II. fig. 13.

C. modica vix semiuncialis, lævis, transversa, oblonga, haud convexa; nate subcentrali eminente. Latus anticus longior rotundatus, posticus truncato-quadratus, carinâ obtusâ a disco sejunctus. Margo ventralis subrectus, haud sinuatus.

In the compressed transverse oblong form, smooth surface, rounded anterior and truncate posterior ends, this resembles many species. But the subcentral beak is much elevated for a shell of this group; the posterior hinge line, too, is almost parallel to the ventral margin (a rare character), straight, and forms a right angle with the truncate posterior edge.

These characters, unusual in the *Nuculæ* of the old rocks, give it somewhat the look of a small *Thracia*. The hinge teeth on both sides of the beak refer it to the Palæozoic *Nuculæ*, which have now for some years been distinguished from the modern ones under the name *Ctenodonta.**

Locality.—As above (*b*).

Another small *Ctenodonta*, of an oblong shape, too obscure to figure here, appears distinct from the English forms (lower quarry.)

Cucullella . . . sp.

Too convex, and with a more rounded posterior side than *C. antiqua.* It does not exactly agree with any of the English species.

Locality.—Same as last (in *b.*)

Acroculia (?) *antiquata*, Pl. II. fig. 17 (18 ?)

A spirally-rolled shell, an inch and a quarter in diameter, with a very small involute spire, and a wide compressed mouth. The whole surface is covered with strong rugæ in the direction of the lines of growth, crossed by fine concentric striæ.

The above characters express the general aspect of this strange shell, which is wholly unlike any figured *Acroculia*, and yet has too wide a mouth and too small a spire for *Cyclonema* or the allied genera.

Spire not a quarter of an inch broad, the apex concealed; the upper margin of the body-whorl narrow, but rounded; the sides flat or compressed, the base oblique, the mouth oval-oblong, an inch long, not above three-quarters of an inch wide.

It is difficult to believe fig. 18, which looks so like a bivalve shell, to be only the young portion of this. But it has the same external markings, the rough rugæ of growth, and the concentric lines; and if not the same species, it must be regarded as of the same genus. The mouth is more expanded than it is in fig. 17, and it should be less so in a young shell of the same species.—Same locality.

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* Siluria, 2nd edition, p. 255.

Platyschisma simulans, n. sp., Pl. II. fig. 19.

Subdiscoid (helicoid), of four whorls, which are each very little convex, except just below the suture; the outer or body-whorl once and a half the width of the preceding. Beneath the whorl is nearly flat, the outer angle therefore is somewhat acute, and has a distinct marginal ridge. In the figured specimen this shows like a band, and if such were really present it would make it a *Pleurotomaria*. I think, however, it is a superficial marking. Umbilicus small, not above a quarter the width of the shell, which does not reach more than half an inch in diameter.

Locality.—Shales (*a*) and grit bed (*c*) of the North Esk section.

I believe the same species occurs in plenty at Lesmahago, in the Upper beds (*Trochus* beds), which underlie the Old Red Sandstone. In both cases the under side of the whorl is flat. while in the (*Trochus*) *helicites* of the Silurian region it is nearly as convex as the upper surface.

In these same beds at Lesmahago (but not yet in the Pentlands) I found abundance of a small *Lingula*, which at first sight recalled the familiar *L. cornea* of the Ludlow Rocks. So did the spiral snail-like shell, the *Platyschisma helicites* of those beds. In both cases the species are distinct. The *Lingula* is a smaller and flatter species, of a more decidedly oval form (*L. unguiculus*, MSS.) The *Beyrichia Klœdeni* accompanied them; and as the other bivalve crustacean described by Mr. Jones is also found in the Silurian country, these minute *Entomostraca* have a very wide range, while the shells have a restricted one.

Cyclonema . . . sp.

Compared with *C.* (*Turbo*) *corallii* of the Silurian System, this species, which is much like it in general aspect, has more inflated whorls (not merely tumid below), and the ridges, five or six in a whorl, are narrow threads, with flat spaces between them, crossed by close lines of growth. It is certainly a distinct species.

Locality.—(*b*) as above.

Loxonema, or *Holopella*,—sp.

A robust species, about an inch long, and rather quickly tapering for the genus, apical angle about 25°; spire of eight whorls, each gently and regularly convex, not more so below than above; lines of growth indistinct; shell thin.

Very like a species in the Lower Ludlow Rock of Ludlow, Shropshire. In the absence of lines of growth the genus cannot be given with certainty.

Locality.—(*b*), as above.

Loxonema, or *Holopella*,—sp.

An elongated turrited shell, eight lines long, very slender, of 13 or 14 whorls, regularly convex, rather tumid in the young portion, and *apparently* smooth.

Locality.—(*a*), in the reddish grit, rare.

Cyrtolites, sp.

Half an inch long, not 2 lines wide at the mouth, curved into a sickle shape, subcylindric, or at least very convex, and with but slightly curved lines of growth. Apex regularly tapering.

This might be described from better specimens. It is not identical with *C. lævis* of the Silurian System.

Locality.—(*b*) as above.

Conularia Sowerbyi, Defrance (Siluria, 2nd ed. pl. xxv., p. 10).

This, and the Pteropods, are more likely than any other *Mollusca*, except *Cephalopoda*, to be common to the Scottish and English Silurian basins. That these basins or seas were separated by a long range of coast line seems to me pretty certain, from the great difference in the Fauna, but pelagic *Mollusca* would find their way, as they do now, into remote, or even well-separated marine provinces.

Locality as before.—(*b*).

Conularia, sp.

A very imperfect fragment of a species distinct from any yet published. It has transverse, not oblique plaits, and the longitudinal furrows seem to be very shallow. It is like some unfigured forms from Shropshire.

Locality, same as last.—(*b*).

Orthoceras McLareni, Salter (Siluria, 2nd ed. p. 176, fig. 24.)

More perfect specimens than that originally found by Maclaren, were obtained by Mr. Geikie and myself, and afterwards by our collector, Mr. R. Gibbs, in 1859.

The shell must have measured 6 or 7 inches at least, and is often an inch wide at the mouth, which has one margin produced, the lines of growth, therefore (on a lateral view*), very oblique and sigmoid. They are crowded near the mouth, but on other parts show as strong sharp ridges imbricating upwards, with a steep forward edge. They are not placed quite regularly, but generally about a line apart (in one large specimen, 14 lines in diameter, they are full 1½ lines apart, but this is rare), and with their imbricate structure give a strongly ridged rough aspect to the shell. The septa, in a specimen probably ¾ inch diameter, are 2 lines apart, and nearly direct.

Locality.—(*b*) as above.

There are two other species, smooth and slender, of the ordinary Silurian type. One from the quarry No. 2, or *b*, has very oblique septa. The other, from the upper quarry openings (*c*), has direct but very convex septa, and the usual central siphon.

It is such smooth or transversely striate species as these, with the septa so convex as to be easily crushed flat sideways, and so lost to view, that induced the late Prof. E. Forbes to suggest the name *Creseis primæva*, &c. for these floating thin-shelled forms. It is extremely probable they were of a different generic type from the thicker-shelled species, with close horizontal or oblique septa, and siphon more or less excentric. But no means are left us now of distinguishing among the crowd of simple *Orthocerata*, and we must be content, as best we may, to indicate the more prominent species in this unwieldy genus. *Orthoceras* appears to be rare in the corresponding schists of Lesmahago, from which one specimen only was described by Sir R. I. Murchison.

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* It is important to observe which aspect of an *Orthoceras* is under view, when embedded. A shell which shows the growth lines very oblique on the sides will have them transverse and straight on the dorsal or ventral view.

No fossils have been obtained from the OLD RED SANDSTONE rocks of the district.

CARBONIFEROUS ROCKS.

The strata round Edinburgh are rich in plant remains,—shells and fish. Full lists of these are here given from Morris' catalogue, Fleming's British Animals, &c., which lists have been carefully abstracted by Mr. Geikie and Dr. Young for these pages. The species which have come under the notice of the Survey have been already partly referred to in the text.

As a rule (not without exceptions) few species of plants pass from the coal-beds beneath the Mountain Limestone into those above them. The subject has yet to be more fully worked out for Britain ; but on the continent the Lower and Upper Coal-bearing measures are well distinguished by their fossils. (See Geinitz, Geognost. Darstellung der Steinkohl. Form. in Sachsen, 1856, fol. p. 8, &c., and Siluria, 2nd ed. pp. 315, 409, &c.)

LOWER CARBONIFEROUS.

Our list includes the fossils of all the beds coloured as Lower Carboniferous on the map, an asterisk being placed against those *peculiar,* so far as we yet know, to the Burdie House limestones.

From the lowest plant beds of the Edinburgh district (those of St. Anthony's Chapel or Arthur's Seat) we have only linear fragments of *Poacites,* or some grass-like plant ? Mr. Geikie obtained, several years back, scales of *Rhizodus* from this spot.

At the Western Breakwater, Granton, Mr. R. Gibbs collected several fossils in a short time, and nine or ten species were found by him and myself in a morning's work at Slateford, a few miles south-east of Edinburgh. Among these was a a beautiful new species of (fern ?) *Adiantites,* not yet published by Sir C. Bunbury, who has provisionally named it *A. Lindseæformis,* MSS. (See description in p. 151.)

On the flanks of the Pentland Hills ; viz., at Clubbidean reservoir (p. 18) some marine beds of the series occur, comparable with those described from the Fife coast by the Rev. T. Brown, Trans. Roy. Soc. Edinb., vol. 22, part 2, p. 401, f. 3. Ferns (*Sphenopteris*), and the ever-recurring *Cypris* or *Cythere,* are found together with truly marine shells, such as *Spirorbis carbonarius,* and a new species, *S. helicteres,* with open whorls. A small oval species of *Myalina* occurs with them.

These fossils, few as they are, show a partial extension of the same marine conditions that obtained in Fifeshire. These will be more fully entered into when that coast is described.

Burdie House Beds.

In the limestones and shales of this series the great fishes *Rhizodus* and *Megalicthys,* with *Cypris,* ferns, *Lepidodendron,* and its fruit *Lepidostrobus,* may be at any time met with. A much larger number of its peculiar fossils may be obtained by sedulous work, and a full list of the fishes has been already given, p. 37.

The *Cypris* or *Cythere,* for it is quite as likely to have been a marine Crustacean, is in every locality. The *Cypridina* (or *Daphnoidea*) *Hibberti* was in all probability marine.

Lower Carboniferous—*cont.*

Plants.

Adiantites Lindseœformis, Bunbury, MSS.	Slateford.
Antholithes Pitcairniæ, Lindl.	Wardie.
A. cristata.	Wardie.
Calamites Lindleyi, Sternb.	Edinburgh.
* *Cardiocarpon acutum*, Brongn.	Burdie House.
Carpolithes sulcatus, Lindl.	Wardie.
Cyclopteris flabellata, Brongn.	Wardie.
C. obliqua, Brongn.	„
C. reniformis, Brongn.	„
C. trichomanoides, Brongn.	„
Hymenophyllites furcata, Göpp.	Wardie.
Lepidodendron elegans, Brongn.	„
* *L. Sternbergii*, Brongn.	Burdie House.
L. variabile, with its own fruit, the *Lepidostrobus variabilis*, Lindl.	Slateford.
Lepidophyllum intermedium, Lindl.	Wardie.
* *Lepidostrobus comosus*, Lindl.	Burdie House.
L. ornatus, Brongn.	Newhaven, Burdie House.
L. variabilis, Lindl.	Newhaven.
Dadoxylon approximatum (its large pith *Sternbergia* of Artis or *Lomatophloios* of Corda).	Edinburgh.
Pinites medullaris, Lindl.	Craigleith.
P. Withami, Lindl.	„
Poacites?—or a like plant.	St. Anthony's Chapel, Arthur's Seat.
Pothocites Grantoni, Patteson.	Granton.
Sagenaria aculeata, Presl.	Wardie.
S. ramosa, Presl.	„
Selaginites patens, Brongn.	Edinburgh.
Sigillaria, sp.	Hillend, Linlithgowshire.
* *Sphenopteris affinis*, Lindl.	Burdie House, Mid Calder.
* *S. bifida*, Lindl.	„
* *S. crassa*, Lindl.	„
S. elegans, Brongn.	Wardie.
S. linearis, Sternb.	Edinburgh.
* *Stigmaria ficoides*, Brongn.	Juniper Green.
Ulodendron Allani, Buckl.	Craigleith.
U. minus, Lindl.	Colinton.

Annelida.

Spirorbis carbonarius, Murch.	Clubbidean Reservoir ; Inchkeith.
S. helicteres, Salter.	Clubbidean Reservoir.

(Brown, Trans. Roy. Soc. Edinb., vol. xxxii. pt. 2. p. 401. f. 3.)

Crustacea.

Cypris Scoto-burdigalensis, Hibb.	Juniper Green.
Cypris,....sp.	Granton ; Clubbidean Reservoir ; Ecclesmachan, Hillend.
Cypridina or (*Daphnoidea*) *Hibberti*, Jones.	Burdie House.

Mollusca.

Avicula ? modioliforme, Brown,	Woodhall.
Anthracomya ? a thin-shelled sp.,	Slateford.
**A ? (Unio) nuciformis*, Hibb.,	Burdie House.
Lingula squamiformis, Phill.,	Wardie.
Myalina, an oval species.	Clubbidean Reservoir ; Aberdour.
Orthoceras attenuatum, Flem.	Livingstone.
O. cylindraceum, Flem.	Livingstone.

Pisces.

Amblypterus nemopterus, Ag.	Newhaven.
A. punctatus, Ag.	—
A. striatus, Ag.	—
A.... sp.	Granton ; Ecclesmachan.
**Cladodus Hibberti*, Ag.	Burdie House.
**C. parvus*, Ag.	—
**Ctenodus Robertsoni*, Ag.	—
**Ctenoptychius denticulatus*, Ag.	—
**C. pectinatus*, Ag.	—
**Diplodus minutus*, Ag.	—
**Eurynotus crenatus*, Ag.	—
E. fimbriatus, Ag.	Newhaven.
Gyracanthus formosus, Ag.	Burdie House.
Rhizodus Hibberti, McCoy.	Burdie House; Arthur's Seat, St. Anthony's Chapel.
(Coprolites of do.),	Granton; Mid Calder ; Hill End ; Slateford.
R. striatus, Ag.	Edinburgh.
Palæoniscus carinatus, Ag.	Newhaven.
**P. ornatissimus*, Ag.	Burdie House.
**P. Robisoni*, Hibb.	—
**P. striolatus*, Ag.	—
**Ptychacanthus sublævis*, Ag.	—
**Pygopterus Bucklandi*, Hibb.	—
**P. Jamesoni*, Ag.	—
**Uronemus lobatus*, Ag.	Burdie House.
*Fish defence, and shagreen.	Mid Calder.

The fossils found in the Burdie House Limestones are for the greater part distinct from those of other parts of the Lower Carboniferous series. This may be partly due to greater attention having been paid to this celebrated limestone by collectors.

Houston, or Binny Coal Group.

Very few fossils were found in these strata. At Hill End, 12 miles west of Edinburgh, the shales contained *Sigillaria*, with *Cypris* and the coprolites of *Rhizodus Hibberti*, as in the Burdie House beds.

CARBONIFEROUS LIMESTONE.

Lower Limestones.

The Scottish type of Mountain Limestone is well developed in Edinburghshire and the county of Haddington. The *three* lower beds of limestone, which lie below the "Edge coals," together with the Upper Limestones, above these, show in the main the same fossils. In the following lists, these three lower bands are separated from the three which lie above the coals, though there is not much difference in their fossil contents.

The lists of Carboniferous Limestone fossils obtained by the Geological Survey have been already in part referred to in the preceding Memoir, and are of course the obvious and more characteristic ones. Those not found by the Survey are marked by an *, and are given from published lists.

The localities are arranged in two columns: east and west of the Pentland Hills.

Zoophytes.

**Alveolites depressa*, Flem.	Bathgate.	
**Astræopora antiqua*, McCoy.	Charleston.	
Aulophyllum fungites, Ph.	Bathgate.	
Clisiophyllum turbinatum, McCoy.	Charleston.	Middleton Limeworks; Whitefield Quarries.
Lithostrotion irregulare, Phill.	Bathgate Hills. Kinniny Point.	
L. junceum, Flem.	—	
L. Flemingii, McCoy.	—	
L. junceum, Edw.	Bathgate.	
Zaphrentis cylindrica, Scouler.	Charleston. Bathgate.	Middleton Limeworks.

Echinodermata.

Actinocrinus, stems of.	Charleston; Kinniny Point; Bathgate.	Middleton Limeworks; Whitefield Quarry; Carlops.
Poteriocrinus, stems of.	Bathgate; Charleston.	
Rhodocrinus, stems of.	Charleston.	
Archæocidaris Urii, Flem.	Charleston.	

Annelida.

**Serpula parallela*, McCoy.	Charleston.	
Annelide burrows,	Bathgate, &c.	

Crustacea.

**Eurypterus Scouleri*, Hibb.	Bathgate.	
Griffithides Eichwaldi, Fischer (*G. mucronatus*, McCoy).		Whitefield Quarries.

Bryozoa.

Ceriopora rhombifera, Phill.	Charleston.	
Fenestella plebeia, McCoy.		Gilmerton.
Fenestella, sp.	Charleston; Bathgate.	Gilmerton; Dalkeith.

Brachiopoda.

Athyris ambigua, Sow.	Bathgate; Charleston.	
**A. planosulcata*, Ph.	Bathgate.	
A. Roissyi, Léveillé.	Charleston; Bathgate.	
A. . . . . sp.	Charleston,	Whitefield Quarries.
**Camarophoria crumena*. Mart.	Bathgate; (Fleming).	
Chonetes Hardrensis, Phill.	Charleston,	Gilmerton.
Discina nitida, Phil.	Kinniny Point,	Whitefield Quarries.
Strophomena crenistria, Phill.	Woodcockdale.	
Lingula mytiloides, Sow.	Charleston.	
Orthis Michelini, Lév.	Charleston.	
O. resupinata, Mart.	Kinniny Point; Bathgate; Charleston.	Middleton Limeworks; Whitefield Quarries.

Productus costatus, Sow.	Charleston.	D'Arcy.
P. fimbriatus, Sow.	Bathgate,	Middleton Limeworks.
P. giganteus, Mart.	Bathgate,	Middleton Limeworks.
P. longispina, Sow.	Bathgate ; Charleston ; Kinniny Point.	Gilmerton ; Middleton ; Whitefield Quarries.
P. Martini, Sow.	Bathgate.	
P. punctatus, Mart.	Charleston,	D'Arcy ; Middleton ; Mount Lothian ; Whitefield Quarries.
P. scabriculus, Mart.	Charleston.	
P. semireticulatus, Mart.	Bathgate ; Charleston ; Kinniny Point.	Gilmerton ; D'Arcy ; Whitefield Quarries.
P. spinulosus, Sow.	Bathgate (Flem.)	
Rhynchonella pleurodon, Sow.	Charleston,	D'Arcy.
Spirifer duplicicostatus. Phill.	Bathgate ; Charleston.	
S. glaber, Mart.	Charleston.	
S. lineatus, Mart.	Middleton ; Dryden ; Cousland.	
S. trigonalis. Mart.	Dryden ; Bathgate ; Charleston.	Middleton ; D'Arcy.
S. Urii, Flem.	Charleston.	
* *S. cristatus*, var. *octoplicatus*.	Bathgate (Davidson).	
Streptorhynchus crenistria, Phill.	Charleston.	
* *Terebratula hastata*, Sow.	Charleston.	
* *T. sacculus*, Mart.	Bathgate, Dunfermline.	
* *T. vesicularis*, De Kon.	Bathgate.	

Lamellibranchiata.

Aviculo-pecten interstitialis, Phill.		Whitefield Quarries.
A. ?....sp.	Charleston,	Gilmerton ; Whitefield Quarries.
Pinna flabelliformis, Mart.	Bathgate.	
Modiola,....sp. ?		Gilmerton.
Sanguinolites costellatus, McCoy.	Charleston; Kinniny Pt.	
Ctenodonta gibbosa, Flem.	Charleston; Kinniny Pt.	
C. attenuata, Flem.	Charleston.	
C. brevirostrum, Phill.	Charleston.	Gilmerton.
Solemya,....sp.		Whitefield Quarries; D'Arcy.

Pteropoda.

Conularia quadrisulcata, Sow.	Charleston,	Whitefield Quarries.

Gasteropoda.

* *Bellerophon decussatus*, Flem.	Linlithgow.	
B. apertus, Flem.	Bathgate,	Middleton Limeworks.
B. striatus, Sow.	Linlithgow.	
B. Urii, Flem.	Charleston,	D'Arcy.
Euomphalus carbonarius, Sow.		Whitefield Quarries.
Loxonema, *sp.*	Charleston,	Gilmerton ; Middleton Limeworks.

Macrocheilus acutus ? Sow.	Charleston.	
M. .... sp.		Gilmerton.
Natica,	Charleston.	

Cephalopoda.

Goniatites, ... sp.		D'Arcy.
**Nautilus marginatus,* Flem.	Bathgate.	
**N. quadratus,* Flem.	West Lothian.	
N. subsulcatus, Phill.		Whitefield Quarries.
N. sulcatus, Sow.	Charleston,	D'Arcy.
N. (like *N. ingens*),		D'Arcy.
Orthoceras annulare, Flem.	Charleston; Linlithgow.	
O. cylindraceum, Flem.	Charleston,	D'Arcy.
**O. læve,* Flem.	Linlithgow.	
O. pyramidale, Flem.	Linlithgow,	D'Arcy.
O. rugosum, Flem.		D'Arcy ; Whitefield Quarries.

Pisces.

**Cochliodus magnus,* Ag.	Bathgate.
**Petalodus,* .... sp.	Charleston.

EDGE COALS.

As shown in a previous part of this Memoir, these coals belong to the Carboniferous Limestone series. They contain numerous plants, which can only be adequately collected by persons resident on the spot. A few plants, *Lepidodendron elegans,* and a *Lepidostrobus,* with *Stigmaria,* were found at Niddry Mill, 2 miles south of Portobello ; the *Rhizodus Hibberti* at Gilmerton, and at Prestonpans Pier a *Lepidodendron* and *Pecopteris.* Mr. Geikie informs me that he obtained *Lingula mytiloides* and an *Anthracosia* from the corresponding coals of Borrowstounness.

UPPER LIMESTONES.

The fossils of these beds are comparatively few, and generally occur in an imperfect state. They are identical, however, with those of the Lower Limestones, and, therefore, show that the Edge coals, with the limestones below and above them, form part of one series, the equivalent of the Carboniferous Limestone of England.

——	Linlithgowshire.	Edinburgh Basin.	
		West Side.	East Side.
Cyathophyllum - -	Woodcockdale, River Avon.	—	Cockenzie.
Archæocidaris Urii, Flem.	—	Joppa	—
Actinocrinus, stems of -	—	—	Ravenshaugh Bridge.
Poteriocrinus, stems -	—	—	"
Chonetes Hardrensis, Phill.	—	—	Cockenzie.
Productus giganteus, Mart.	Kinniel, River Avon.	Penicuick, Joppa	"
P. semireticulatus, Mart. -	—	Joppa	Bankfoot ; Prestonpans.
P. fimbriatus, Sow. - -	—	Penicuick	Cockenzie.
P. longispina, Sow. - -	—	Joppa	Bankfoot ; Cockenzie.
Streptorhynchus crenistria (*Orthis,* Phillips).	Woodcock Dale -	Valleyfield, Penicuick.	Bankfoot.
Orthis resupinata, Mart. -	—	Do.	—
Strophalosia striata, Fischer	—	Do.	—

—	Linlithgowshire.	Edinburgh Basin.	
		West Side.	East Side.
Spirifer trigonalis, Mart. -	—	—	Cockenzie,
Schizodus, sp. - -	—	Joppa	—
Ctenodonta attenuata, Flem.	Woodcockdale -	—	—
Chemnitzia (slender close turretted whorls).	—	—	Cockenzie (abundant).
Macrocheilus (small sp.) -	—	—	Do.
Bellerophon decussatus, Flem.	—	Joppa	Prestonpans.
B. Urii, Flem. - -	—	Do.	—
Stigmaria, roots - -	—	—	Wallyford House
Sphenopteris elegans, Brongn.	—	—	"
Seaweed (*Cauda galli*) on surfaces of sandstone.	—	—	Ravenshaugh Bridge.

The last fossil on this list was observed, in 1854, at Dunbar by Professor Ramsay, who then considered it a seaweed, and it was afterwards found by him to resemble the fossil known in American Silurian Rocks by the name of *Cauda galli*. It is very abundant on the Lower Limestones and Sandstones of Haddingtonshire; and though its amorphous form makes it appear at first sight inorganic, a close examination shows that it has a regular wavy surface, with ribs or ridges, and a fimbriated border.

MILLSTONE GRIT.

The beds of sandstone which are believed to occupy the place of the Millstone Grit seem to contain few or no fossils in the Edinburgh district. A careful search, by Mr. R. Gibbs (1860), among the corresponding beds of Fife, has yielded a few fossils, which are only Carboniferous Limestone species, or such as are found at the sandy base of the true Coal Measures. They are—*Productus semireticulatus; Lingula mytiloides;* a *Modiola*, a species of *Macrocheilus;* and *Serpula*.

More will be said of this formation when the description of the Fife sheet is printed.

FLAT COALS.

The fossils of the Flat Coals, equivalent to the true Coal Measures of England, are, as yet, very imperfectly collected, and can only be satisfactorily obtained by persons resident in the district.

The following list shows what have been observed in the course of the survey :—

Lepidodendron.			Shawfair, 2 miles south of Portobello.
Sphenopteris.	Inveresk.		
Pecopteris.	Inv.	Near Squaretown, between Portobello and Dalkeith.	
Asterophyllites.	Inv.	—	
Calamites.	Inv.	E. of Sq.	
Modiola or *Myalina.*		—	Sh.
Myalina, sp.		Squaretown.	Sh.
Anthracosia acuta.		Sq.	—
A., sp.		—	Sh,
Rhizodus, sp.		Sq.	Sh.
Megalicthys Hibberti.		—	Sh.
Pleuracanthus.		Sq.	—
blypterus.		Sq.	—

Ctenacanthus hybodoides and ***C. nodosus***, Egerton, have been described from Dalkeith (Quart. Geol. Journ. vol. ix. p. 280).

At Harelaw the coal is chiefly made up of the ***sporangia*** of some ***Lepidodendron*** or like plant; a few fishes (chiefly ***Megalicthys***) occur with it.

The new plant from the Lower Carboniferous referred to in p. 144 is the

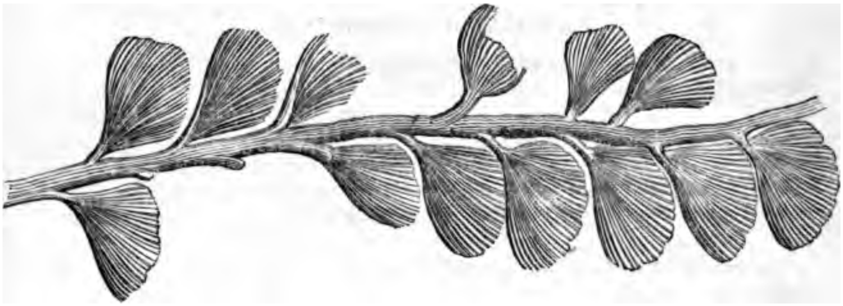
Adiantites Lindseæformis. Bunbury.

"This would probably fall under Lesquereux's genus *Nöggerathia*, which appears to me to be very different from Brongniart's genus of that name, and not to differ essentially from *Adiantites*.*

"Frond pinnate; rhachis thick, striate; pinnules alternate, nearly sessile, between crescent and fan-shaped (*lunulato-flabellata*), expanding from a very narrow base; the inner edge vertical, straight, contiguous to the rhachis; upper margin waved, subcrenate. Veins strong, numerous, close, repeatedly dichotomous, diverging from the base.

"This beautiful and new species much resembles *Lindsæa*, especially such species as *L. Guianensis*, *L. stricta*, and *L. quadrangularis*, but differs (as fossil ferns frequently do from their nearest recent allies) in the proportionally much thicker stalk."—C.F.B.

Fig. 26.



Adiantites Lindseæformis. Bunbury MSS.

Locality.—It occurred, two or three specimens, in the dark tough Lower Carboniferous Shales of Slateford, S.W. of Edinburgh, in company with the *Lepidostrobus variabilis?* or a new species, which is abundant there; and with a marine shell (*Anthracomya*).

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* Lesquereux in H. D. Rogers' Geol. of Pennsylvania.

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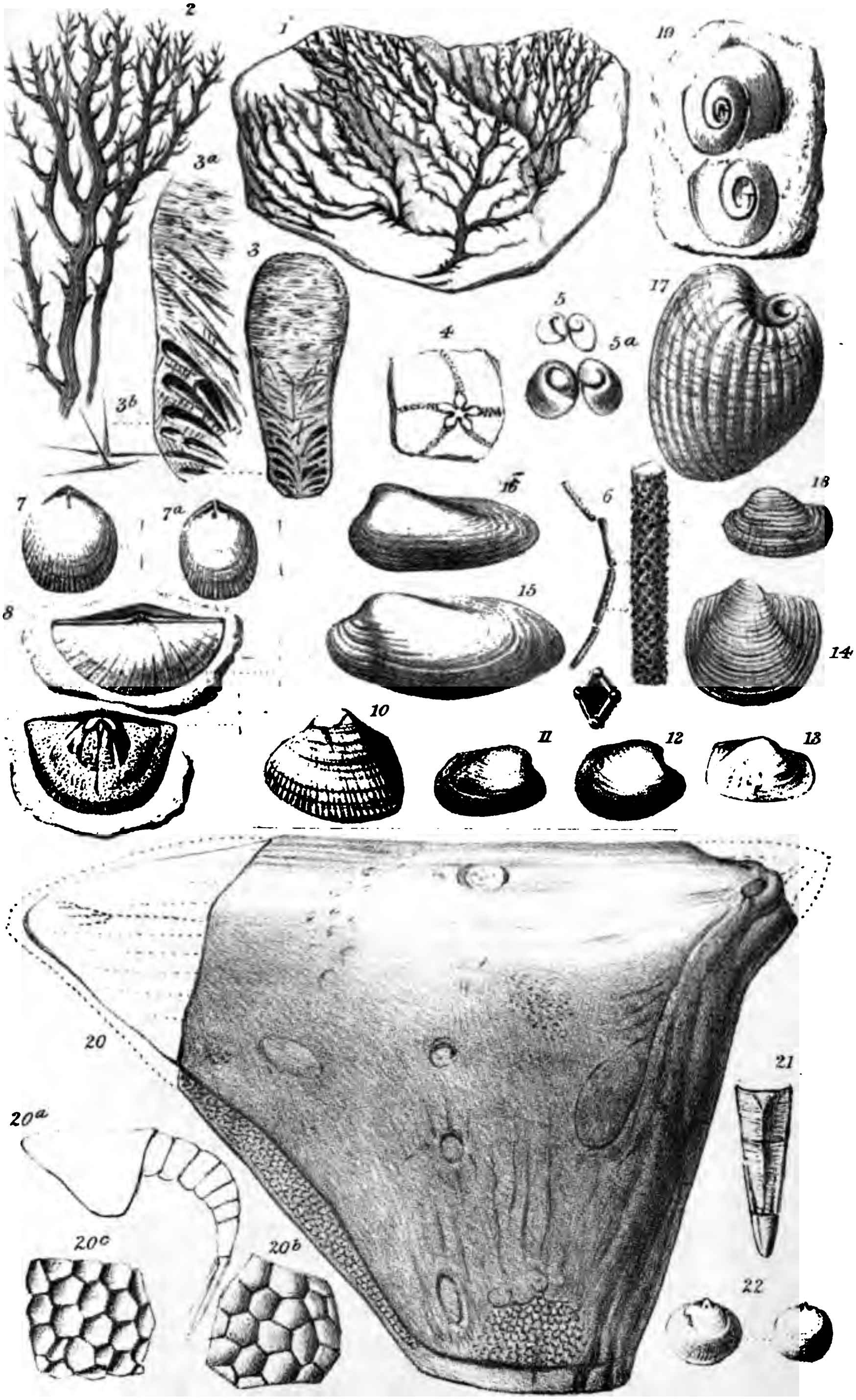
PLATE II

UPPER LUDLOW ROCK.



J. W. Salter del. C. R. Bone lith.

Day & Son Lithrs

SILURIAN FOSSILS OF THE PENTLAND HILLS.